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MONSANTO INDUSTRIAL CHEMICAL CO.

MONAR
1.8-2

Report

on

HYDROGEOLOGICAL INVESTIGATION

SODA SPRINGS PLANT SITE

Soda Springs, Idaho

VOLUME 2
Appendices D - G

6298

September, 1985

Golder Associates

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

REPORT TO
MONSANTO INDUSTRIAL CHEMICAL COMPANY
ON
HYDROGEOLOGICAL INVESTIGATION
SODA SPRINGS PLANT SITE
SODA SPRINGS, IDAHO

VOLUME 2

APPENDICES D–G

DISTRIBUTION:

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September, 1985

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VOLUME 2

TABLE OF CONTENTS

APPENDIX D

FIELD BOREHOLE LOGS AND HISTORY OF HOLE

TW 9

i) Schematic Test Well Completion

ii) Field Borehole Log

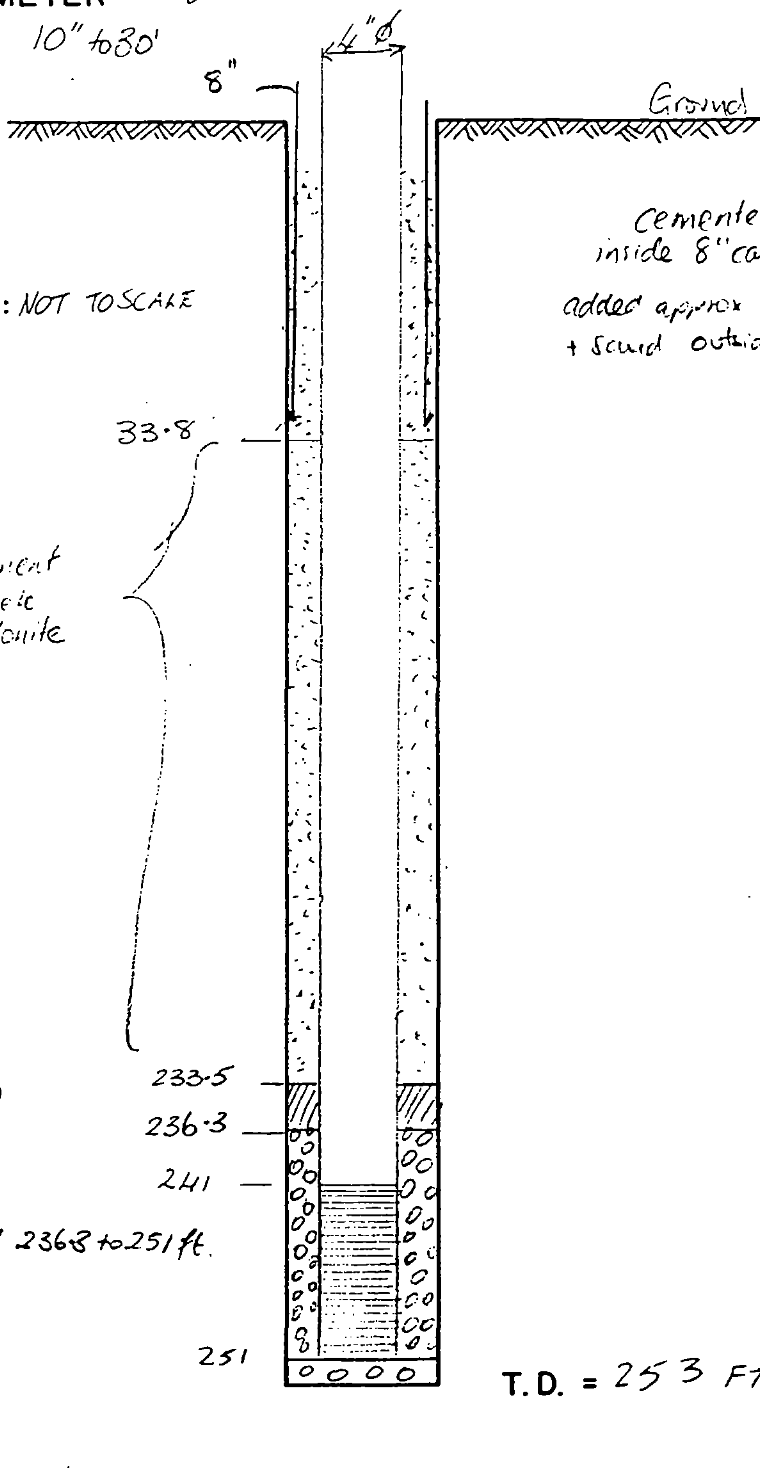
iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA

Figure

BOREHOLE *TW 9.*

HOLE DIAMETER *8" to 253'*
10" to 30'



REMARKS: *NOT TO SCALE*

cemented inside 8" casing to ≈5'

added approx 1 yard of cement + sand outside 8" casing 31/01/84

GROUT
TOTAL OF 110 bags cement
½ bag flocele
½ bag bentonite

200 lbs bentonite (some may have hung up)

6 pails gravel 236.3 to 251 ft.

1 pail gravel

T.D. = *253 FT*

PROJECT .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW9
Sheet 1 of

Project: MONSANTO GROUNDWATER STUDY

Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E
N
Angle from horizontal: 90°
Bearing: — ° Azimuth

Reference elevation:
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ft	(2) (4) Water Level ft	(5) Water Flow USgpm	(6) ~~Other~~ Penetration Rate mins/ft	After Drilling: (2) (7) Water Level T°C	Permeability: (2) Depth C	Method pH	(8) Value (cm/s)	Comments
Ground Surface										
brown silty CLAY trace sand (0 – 12.5)	10" 8" 4"									
grey faintly weathered, BASALT (12.5 – 24.0)										
red/brown Loose BASALT and CINDERS some clay (24.0 – 30.0) Scoria		24	11.9	30-50		14		7.73		
	31					15		7.79		
Fresh Basalt (30.0 – 51)						15		7.23		
						14		7.27		
		42	12.95							
						14		7.22		
					9					
						13		7.20		
red/brown faint weathered vesicular BASALT (51 – 57)					2.2					
						12		7.1		
					4					
grey fresh BASALT (57 – 78.0)						12		7.16		
					5					
		67	12.2			12		7.27		
					6					
						11		7.06		
					5					
						11		7.35		
					2					
reddish/brown faintly weathered BASALT with some cinders (78.0 – 89.0)						12		7.32		
					3					
						12		7.42		Water sample from 88 ft F = .41 mg/l.
					4					
						12		7.35		

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: ANDREW WELL DRILLING
Logged by: DB/MS
Date started: 17/08/84
Checked by:
Date finished:
Date:

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW9
Sheet 2 of ....

Project MONSANTO GROUNDWATER STUDY

Type of drilling ....
Rig ....
Drilling fluid ....

Coordinates: E ....
N ....
Angle from horizontal ....
Bearing .... °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ....

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2)(4) Water Level ~~(m)~~	(5) Water Flow ~~(L/s)~~	(6) ~~Other~~ Penetr. Rate	After Drilling (2)(7) Water ~~Level~~ (m)	Permeability (8) (2) Depth ~~(m)~~	~~Method~~	~~Value (cm/s)~~	Comments
Contd		ft	AE	VSgpm	mm/ft	T	C	pH		
Fresh grey olivine BASALT	8" 4"				6					
						12		7.40		
					5					
		100				13		7.44		
					4.4					
						12		7.46		
					4					
		110				12		7.54		
					7.4					
119										
CLAY 121		120			2.5	14		7.39		
						13		7.50		
		130			4.5	14		7.59		
						15	1350	7.57		
Fresh grey olivine BASALT					5					
		140				13	1400	7.35		
					6					
						14	1350	7.33		
					6					
		150				15	1500	—		new bit
					6					
						14	1550	7.23		
					5					
		160				14	1650	7.19		
					6					
						14	1600	7.16		
					10					
		170				13	1600	7.13		
					5					
						13	1600	7.2		
					4					
		180				13	1600	7.35		

Contractor: ....
Date started: ....
Date finished: ....

Logged by: ....
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW9
Sheet 3 of 3

Project MONSANTO GROUNDWATER STUDY

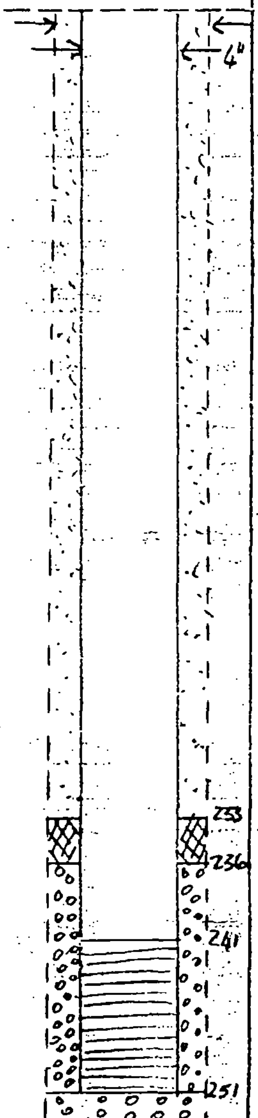
Type of drilling ....
Rig ....
Drilling fluid ....

Coordinates: E ....
N ....
Angle from horizontal ....
Bearing .... °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ....

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(L/s)~~ USgpm	(6) Other Penetration Rate min/ft	After Drilling: (2)(7) ~~Water Level (m)~~ T °C	Permeability (8): (2) ~~Depth (m)~~ C	~~Method~~ pH	~~Value (cm/s)~~	Comments
Cont'd										
181 Sl. weathered BASALT 182	8" / 4"				4	13	1600	7.34		
Fresh grey olivine BASALT		186	12.3		4	9	1150	7.34		
190					6	10	1150	7.44		
					4.8	12	1150	7.47		
200					4	12	1250	7.47		
205 Sl. weathered reddish grey BASALT 207					9.2	12	1225	7.56		Water sample from 210 ft F = .55 mg/l.
210 Fresh grey olivine BASALT					4.2	13	1275	7.60		
					7.8	13	1250	7.52		
220					8	13	1350	7.51		
224 Sl. weathered reddish grey BASALT 226					6.6	13	1300	7.25		
230 Fresh grey olivine BASALT	233				6.4	14	1650	7.35		
	236				4.6	14	1300	7.58		
240 Sl. weathered reddish grey vuggy BASALT 243	241				3.4	16	1450	7.37		
Fresh grey BASALT 246; Sl. weathered reddish grey vuggy BASALT 250					5	15	1300	7.01		
250 Fresh grey BASALT 253	251									
End of Hole										



Contractor: ....
Date started: ....
Date finished: ....
Logged by: ....
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW9

GEOLOGIST: D. Banton DATE: 08/17/84

8:30 - 9:00	Set up on hole.
9:00	Start drilling with hammer 8" diameter.
9:10 - 9:20	Change from hammer to tricone. Bedrock at 12'6" set 13'14", 8" casing to ground level. Water at 24' cinder zone, water level 11'11" below ground - bubbling.
12:00	Driller and helper take lunch. Hole depth = 42' at lunch - water heard running into hole, probably from cinder zone. Water level 13'1" below ground at 12:40 p.m.
1:00 - 2:30	Drilling to 47' - hook up compressor to lift cave out of hole. 1:20 - 1:45 wait for loader to dig soak pit.
2:40	Pull rods due to cave.
2:50	Pull 8" casing to allow hole to be reamed at 10" diameter.
3:10	Run 10" diameter bit into hole and ream.
3:20 - 3:40	Wait for trash pump to pump out soak pit.
3:40	Restart reaming.
4:10	Run 18'10" casing into hole to stabilize overburden.
4:25	Restart 10" reaming. Reamed to 27' by 5:00 p.m.

NOTES: Response to drilling TW9 seen in TW7.
Later, when TW8 hooked up, immediate response to airlifting TW9.

HISTORY OF HOLE

TW9

GEOLOGIST: D. Banton / M. Shaleen DATE: 08/20/84

10:00	Hole caved about 2' overnight, run 8" casing to 29'4". Restart drilling - caving problems, push casing to 31', add more casing and push to 31 ft. Drill appears to have deviated from original hole. Restart drilling - less cinders (probably sealed off cinder zone).
1:00 - 1:35	Lunch.
1:35	Change from tricone to downhole hammer. Hook up extra compressor to aid airlift. Very slow drilling to 44'.
3:10	Filter on compressor needs replacing. Down 3:10 - 4:25 p.m. Add foam to try to lift cuttings.
4:50	Pull hammer and change to tricone - hammer very slow.
4:50 - 7:20	Drilling with tricone 43 to 67'.

DATE: 08/21/84

7:30	Drilling from 67' using extra compressor. Pass through basalt and occasional cinder zones. Drilled to 146' by 1:45 p.m. Driller notes bit locking. Pull rods - tricone roller is worn. Replace bit and rerun rods - drilling much smoother. Some foam added at 167' then off at 169'.
4:50	Fuel leak in compressor, driller leave to find fitting.
5:30	Restart drilling at 169'.
6:50	Finish at 186'.

COMMENTS: Reference solution for conductivity meter arrived. Hatch instrument way off.

Change to YSI meter from Hatch conductivity meter at 135' and took both meter measurements for comparison - very few cinder zones below 119'. Good progress, very little change in water quality.

HISTORY OF HOLE

TW9

GEOLOGIST: D. Banton / M. Shaleen DATE: 08/22/84

7:15	Drill from 186' through generally fresh, non-vuggy basalt. Few weathered basalt zones/vuggy between 200 to 210' and 240 to 250'. Drilling stopped at 1:25 at 250' (although subsequent geophysical logging showed hole to be 253' deep). Rods pulled out by 3:00 p.m.
3:00 - 7:00	Run geophysical logs with assistance from Roscoe Bolton (Monsanto). Gamma log okay. Resistivity and S.P. - had to check manual since Monsanto personnel were not familiar with these logs.

HISTORY OF HOLE

TW9

GEOLOGIST: D. Banton / M. Shaleen DATE: 08/23/84

9:15 Start well completion:

Run 1 x 10' 20 slot screen (Lengths are slightly less)
12 x 20' blank PVC (than given values due to loss)
1 x 10' blank PVC (of a few inches/thread)
Centralizers every 40' threads wrapped with teflon.

Base of well sounded to 251' (2' gravel below screen).

Backfill around screen w/gravel to 236.3'. 6 x 5 gallon pails of gravel added.

Added bentonite pellets to 233.5' below ground. 200 lb bentonite for approximate 3' seal.

Added further 50 lbs but no change in sounded depth. Presume bentonite hung up in hole. Could not dislodge with tremie pipe. Tremie pipe 231' long.

Wait 1 hour for cement truck
Cement is 75 bags x 6 gals water for 450 U.S.gal
Added 1-1/2 bags Flocele and 50 lbs powdered bentonite. Mixed another 10 mins. before pumping into hole. After pumping for approximately 2 to 3 mins., pump stops, increase air pressure to pump and pump explodes.

Pump dismantled - well rounded 1/2 to 3/4"Ø gravel found in pump - appears to have come from cement truck and blocked pump. Rest of cement pumped at surface and tremie pipe pulled from 230' to 80' below table.

Water level in TW9 at 6:30 p.m. - 2.12 m

Well sounded to 253' below top of PVC pipe.

HISTORY OF HOLE

TW9

GEOLOGIST: D. Banton / M. Shaleen DATE: 08/24/84

11:15 - 12:30 Drillers reconnect damaged mud pump. Tremie pipe blocked at 70' - pull out pipe - cement inside - clean out. Lunch 1:00 to 2:00 p.m. Run tremie pipe - pipe will not advance beyond 63'. Run sounder to 141' below ground - feels soft. Probe in bentonite that did not fall to base of hole.

3:30 Drillers order cement. 50 bags x 6 gals water.

5:15 Cement arrives - add bentonite 1/2 bag and Flocene 1/2 bag. Pump grout - hole does not fill. Mix and add 40 bags cement and 1/2 bag bentonite - no Flocele. Pump grout. Cement sounded to 41' below casing.-

7:30 Pull tremie pipe. Depth to water in well at start of shift - 2.07 m (6.79'). Base of well sounded to 251' below ground level.

DATE: 08/28/84

Added cement grout to well annulus - 5-1/2 gals water per bag of cement. Filled to 17.9' between 4" and 8" casing, and to 16.7' outside casing.

DATE: 08/31/84

Added 3/4 yard 3:1 sand/cement mixture to well annulus - filled to approximately 5' inside 8" casing and 11' outside casing.

DATE: 10/22/84

Cemented outside 8" casing with 200 gals water and 36 bags cement.

WELL DEVELOPMENT - TW9

A submersible pump was placed in TW9 on September 24th, 1984. The pump was set to a depth of approximately 40 ft below T.O.C. The pump was switched on at 13:45 and pumped for approximately 1-1/2 mins before the water level reached the intake. Measurements taken during recovery are shown on attached sheet. The well was allowed to partially recover before being pumped again. In all, the well was pumped four times and then allowed to recover. A sample was taken by Monsanto from the discharge of the fourth pumping cycle. Chemical parameters measured at each pumping cycle are given below:

	Cycle Number			
	1	2	3	4
T °C	12	10	9	8.5
C (μmhos/cm)	1240	1300	1300	1300
pH	6.26	6.24	6.26	6.21*
Eh (mV)	+171	+52	+30	+30

*Monsanto pH analysis = 5.7

Following the test, the Golder pH meter was rechecked for calibration and was seen to read 7.28 in pH 7 Buffer.

TW 10

i) Schematic Test Well Completion

ii) Field Borehole Log

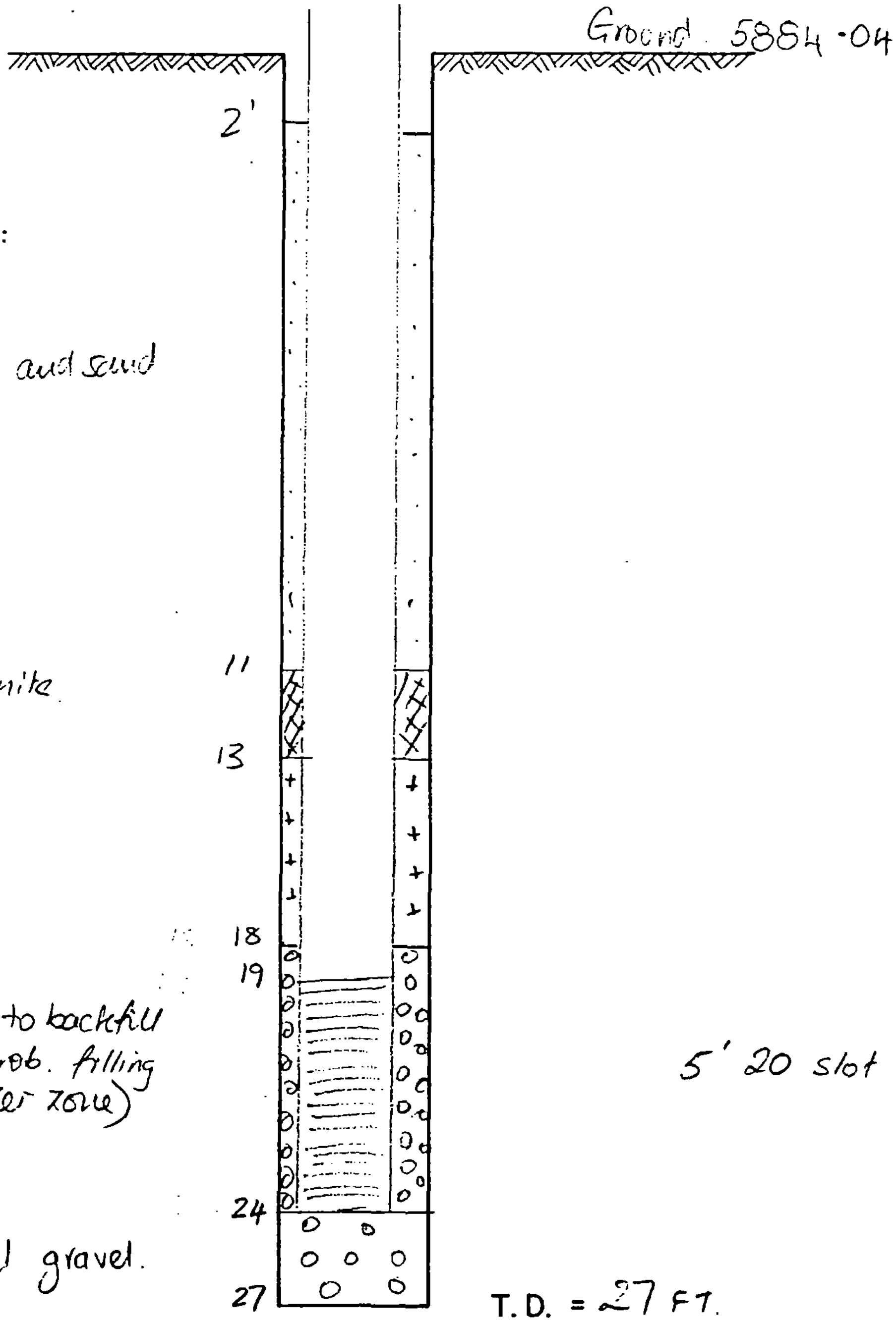
iii) History of Hole and Well Development

~~PIEZOMETER~~ INSTALLATION DATA
WELL

Figure

BOREHOLE TW 10

HOLE DIAMETER 10" to 21 FT
8" to 27 FT



<u>REMARKS</u>:

Not to scale.

2¼ yard Cement and sand to 2'

120 lbs bentonite

Cave

18 pails of gravel to backfill from 24 to 18' (prob. filling in washed out cinder zone)

5' 20 slot PVC

1 pail gravel.

T.D. = 27 FT.

PROJ. NO. .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

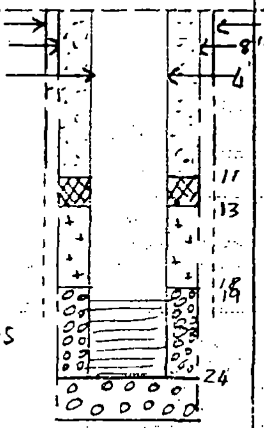
DRILLHOLE No. TW 10
Sheet 1 of 1

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR / WATER

Coordinates: E
N
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation:
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2) (4) Water Level ~~(m)~~	(5) Water Flow ~~(L/s)~~	(6) Other	After Drilling (2) (7) Water Level (m)	~~Permeability~~ (2) Depth (m)	~~Method~~	(8) Value (cm/s)	Comments
Ground Surface		ft	ft	USgpm		T	C	pH		
brown silty CLAY trace gravel (0–10)										
grey faintly weathered BASALT (10–19)										
20 red/brown Nesth BASALT and scoriaceous CINDERS 25		19		30		16	1200	7.85		
Fresh grey BASALT 27										
End of Hole 30										

Please draft at 1:100 Imperial

Contractor: Andrew Well Drilling
Logged by: DB/MS.
Date started: 27th August 1984
Checked by:
Date finished: 28th August 1984
Date:

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW10

GEOLOGIST: D. Banton / M. Shaleen DATE: 08/27/84

9:00 - 9:30	Move and set up.
9:30	Start drilling 10"Ø open hole - set 10" casing to 11' below ground (bedrock). Caving fractured basalt (weathered zone) at 19'. Run 8" casing and redrill zone to 25'. Drilled open hole 25 to 27' - less fractured rock.
3:00 - 3:30	Runn gamma Log.
3:30	Start well completion - 5' screen set 24.9 to 19.9' below ground - gravel pack to 18.9' below ground. Added 4' bentonite and pulled casing - screen pulled out with casing due to bentonite plugging annulus.
5:45 - 6:30	Redrill hole and run 8" casing to 25'. Added gravel to 24.1' and set screen and riser.

DATE: 08/28/84

7:15 - 8:45	Add gravel around screen - much more gravel added than first attempt, probably due to washout during redrilling. Gravel to 18'. Casing pulled - cave 18 to 13', bentonite 13 to 11'.

DATE: 08/31/84

Backfilled 11 - 2' with cement grout (thick). Sand and cement approximately 3:1 mixture.

WELL DEVELOPMENT - TW10

TW10 was developed on September 20th, 1984, using a submersible pump set to a depth of 24 ft in the well. The well was pumped at a rate of 15 gpm for a period of 45 minutes. Chemical parameters of the discharge water are tabulated below. Water level measurements were taken on TW7 during well development.

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH	Eh (mV)
4	13	1100	6.46	+197
17	13.5	1050	6.58	+162
37	14	1050	6.6	+170

The water level in TW7 drew down approximately 0.03 ft during the test.

TW 11

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure /

BOREHOLE TW 11

HOLE DIAMETER 0-27 FT 12"
27-100 10"
100-142 8"

REMARKS:

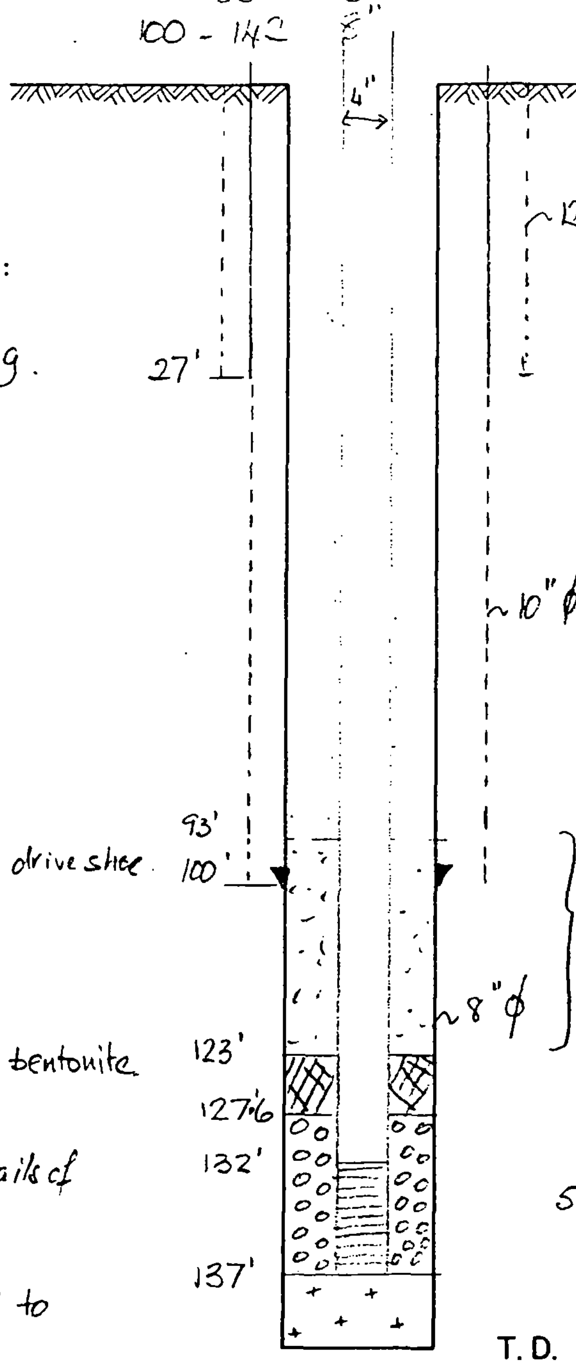
10" casing.

8" casing with drive shoe

3x20lb buckets of bentonite

37x 5gallon pails of pea gravel

Caved to



Cement slurry 125gals H_2O
23 bags cement
25lbs bent
5lb flocele.
(prob lost much of cement out cut in casing at 93')

5' 20 slot PVC

T.D. = 142'

PROJECT NO. DRAWN REVIEWED DATE

HYDROGEOLOGIC LOG

DRILLHOLE No. TW 11
Sheet 1 of 2

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER
Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth
Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	(2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ USgpm	(6) ~~Other~~ Penetr. Rate mins/ft	(2)(7) Water Level ~~(m)~~ Tt	(2) Depth ~~(m)~~ C	Method pH	Value ~~(cm/s)~~ eH	Comments
Ground Surface										
brown silty CLAY trace gravel and sand (0–15.0)	12" 10" 8" 4"									
grey moderately weathered BASALT some clay and silty sand (15.0–23)										Drilling with down hole hammer 15-77 FT
					3.5					
grey fresh vuggy BASALT (23–26)	27				3.4					
grey fresh BASALT with some fine SAND horizons (26–32)					3.0					
Fresh grey BASALT (32–54)					5.0					
					9.2					
					16.0					
					3.4					
red/brown SILT (54–56)										
weathered BASALT with red/brown silty SAND (56–66)					7.2					damp at 65 ft.
					7.0					
Fresh grey BASALT (66–89)					8.0					
					9.0					Drilling with tricone 77-100'
					11.6					
					2.5	13	1300	—	—	Water sample at 87 ft
					5.0	10	1400	7.85	—	F = 0.28 mg/l

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling
Date started: 28th August 1984
Date finished: ....
Logged by: DB/MS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale: IMPERIAL ~~PLEASE~~

Change to imperial 1:180

HYDROGEOLOGIC LOG

DRILLHOLE - No. TW 11
Sheet 2 of 2

Project: MONSANTO GROUNDWATER STUDY

Type of drilling .... Coordinates: E .... N ....

Rig .... Angle from horizontal ....

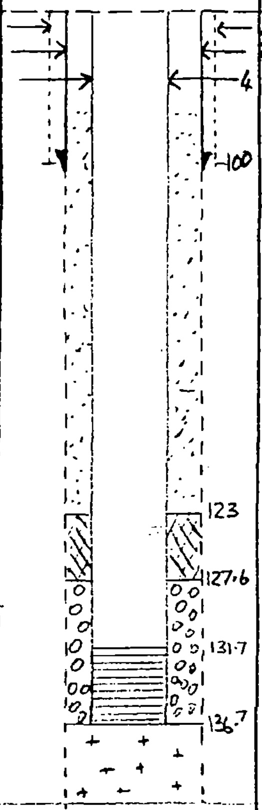
Drilling fluid .... Bearing .... ° Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

Job No. ....



(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2)(4) Water Level ~~(m)~~	(5) Water Flow ~~(l/s)~~	(6) ~~Other~~ Penetr Rate	After ~~Drilling~~ (2)(7) ~~Water Level (m)~~	~~Permeability~~ (8) (2) ~~Depth (m)~~	~~Method~~	~~Value (cm/s)~~	Comments
cont'd		ft	ft	USgpm	mins/ft	T°C	C	pH	eH	
red/brown slightly weathered loose scoriacious CINDERS				50	/					
100 — 100		100	63.3		/					Downhole hammer 100 - 118 FT
Fresh grey BASALT					7.0	12	1450	8.60	-1	
110					6.0	12	1400	8.52	+94	
					14.8	12	1500	8.41	+118	
120					7.0	13	1650	8.18	+110	Drilling with Tricone bit 118 - 142 FT.
					6.0	15	1650	8.12	+116	
129					4.0	13	1300	7.7	+125	
130 red/brown silty fine SAND 132										
Sandy GRAVEL to GRAVEL					/					
		136	63.5	50-75	/	11	1000	7.21	+146	
140 — 142										
End of Borehole.										
150.										

Contractor: Andrew Well Drilling Logged by: DB/MS

Date started: .... Checked by: ....

Date finished: .... Date ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW11

GEOLOGIST: D. Banton / M. Shaleen DATE: 08/28/84

3:30 p.m.	Start drilling TW11 - drilled 8"Ø to 20 by 4 p.m. Bedrock at 15'.
4:00	Run 8" casing to 9' - can't push any further.
4:35	Drilling from 20 to 23'.

DATE: 08/29/84

Drilling from 23' using downhole hammer. Cuttings not returned at 38'. No water. Drilling very slow 43 to 54' - maybe hammer is not working properly. Faster drilling at 54' through weathered cinders. Little return of cuttings between 56' and 64' - very slow drilling. 74' pull hammer and change to smaller choke to try to increase penetration rate - no success. 78' change to tricone bit - hole makes water and cuttings. Drilling much faster with tricone - drilled to 87' by end of day.

HISTORY OF HOLE

TW11

GEOLOGIST: D. Banton / M. Shaleen DATE: 08/30/84

7:45 - 8:30	Try to fix hammer - could not see anything wrong. Hole sounded - blocked at 22' - probably caving from weathered basalt.
9:15 - 9:45	Pull 8" casing and ream to 30'.
9:45	Run 29-1/2' 8" casing - can't push further than 26' below ground.
10:30	Run rods and start drilling. Water sample from 87' given to Monsanto for analysis. Enter caving cinder zone/weathered vesicular basalt at 89', drilled to 94' but still no sound rock. Circulation problems.
	Decide to log hole - 12:00 - 2:00 Lunch 12:00 - 1:00.
1:00 - 4:00	Standby.
4:00	Drilling through cinders to try to grout off zone.
6:00	Drilled to 102' - cinders to approximately 101', but still falling into hole.
6:00 - 7:00	Repairing mud pump - unloading.
7:00 - 9:45	Run tremie pipe to 84'. Add 125 gals water to grout tank. Add 24 bags cement/40 lbs $CaCl_2$. Grout pumped into hole and left overnight.

HISTORY OF HOLE

TW11

GEOLOGIST: D. Banton / M. Shaleen DATE: 08/31/84

8:00	Sound well - to 99' below ground - feels slightly soft at bottom, but apparently no grout in cinder zone. Water level 64' below ground.
8:30	Run rods and drill from 99' - very little return, no cement seen.
9:00 - 11:30	Standby.
11:30	Order thick cement slurry from Parsons - 2-1/2 yds. With 7 bags cement per 40 gals - 2700 lbs sand/yd; 20 lbs $CaCl_2$; 25 lbs Flocele; total. (Estimate 30"Ø hole 12' deep = 2.3 yds).
1:30	Cement arrives - poured into hole slowly - sounded during addition - cinder zone is being filled up. Following all cement, hole sounded to 63' (some 25' above top of cinder zone). This 25' section would hold approximately 1/2 yd. Therefore, about 2 yds went into cinder zone. Cement left to set over weekend.

DATE: 09/04/84

5:00	Moved back onto hole. Ran rods to 63', drilling with hammer. Drilled to 88' - very little return - just a few flakes of Flocele, but drilled hard. 88' rods fell under own weight to 102' - no return. Added foam - return of foam and fine to medium sand and water. Appears that cement did not set - probably was washed away in cinder zone leaving sand - zone was not sealed.
6:45	Pull rods.

HISTORY OF HOLE

TW11

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/06/84

3:00	Pull 8" casing from hole.
3:45	Drilling 12"Ø open hole 0 to 27' - driller notes that hole is starting to cave at this depth. Set 27'2" 10"Ø casing.
5:30 - 7:30	Reamed hole at 10"Ø to 100'.

DATE: 09/07/84

Hole sounded = 100.8' below ground. Run 8" casing to 27' - casing will not move freely below 27' probably due to tight fit between 9-1/8"Ø hole (nominal 10") and outside of 8" drive show (9-1/2"). Casing hammer set up and casing tapped to 100', then driven to seat in solid rock. Drilled out material in 8" pipe.

DATE: 09/10/84

Drilling from 102' using extra compressor and downhole hammer. Slow progress 110 to 118' - pull hammer and use tricone - drilling speed increased. Encountered caving gravel zone at 132' - drilled through to 142', but hole would not stay open beyond 137 ft. Logged gamma and resistivity.

HISTORY OF HOLE

TW11

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/11/84

Ran cutter to approximately 95'. Turned on air and left to rotate for 3/4 hr. Pull rods, examined cutter - appeared to have cut through casing. Set 4" screen and riser - 1x5' length 20 slot PVC + 7x20' length blank PVC + teflon tape cap on bottom of screen. Set base of screen at 136.7'. Backfilled with 37 - 5 gal pails of pea gravel to 127.6'. Added 3x20 lb bentonite pellet pails to 123'. Try to pull 8" casing using hammer and top head. Hammered on casing for about 2 hrs - no movement.

DATE: 09/12/84

Mixed up one load of grout - 125 gals water; 23 bags cement; 25 lbs bentonite; 5 lbs Flocele. Pumped via tremie pipe to 84' below ground.

DATE: 09/13/84

Sounded inside 8" pipe to 29.05 m (93.3') below ground level - slurry has probably been lost via cut in 8" pipe at this depth. Added about 5' sand to annulus to 90.55'.

DATE: 09/17/84

Ran 1" pipe to 100' in well developed with air for 1 hr : 20 mins - water initially dirty - fine sand but soon cleared up. Chemical parameters given on attached sheet. 1" pipe then ran to bottom of well - very dirty water, probably due to air entering screen and disturbing fine sand layer. 1" pipe pulled back to 120' and well developed for 20 mins - water clears up.

WELL DEVELOPMENT - TW11

TW11 was developed on September 17th, 1984. The well was airlifted for 80 mins with 1 in. pipe set at 100 ft. Below is a summary of chemical quality measured during development.

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	Eh (mV)
5	10	1100	7.67	+165
20	10	1050	7.76	+146
40	10.5	1050	7.84	+139
50	10	1050	8.05	+147
70	11	1100	7.96	+141*

*Sample for Monsanto

Airlifting blew 10 to 15 USgpm from the well.

With 1 in. pipe set at 125 ft, approximately 20 to 30 USgpm were airlifted. No drawdown was measured in TW12.

TW 12

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

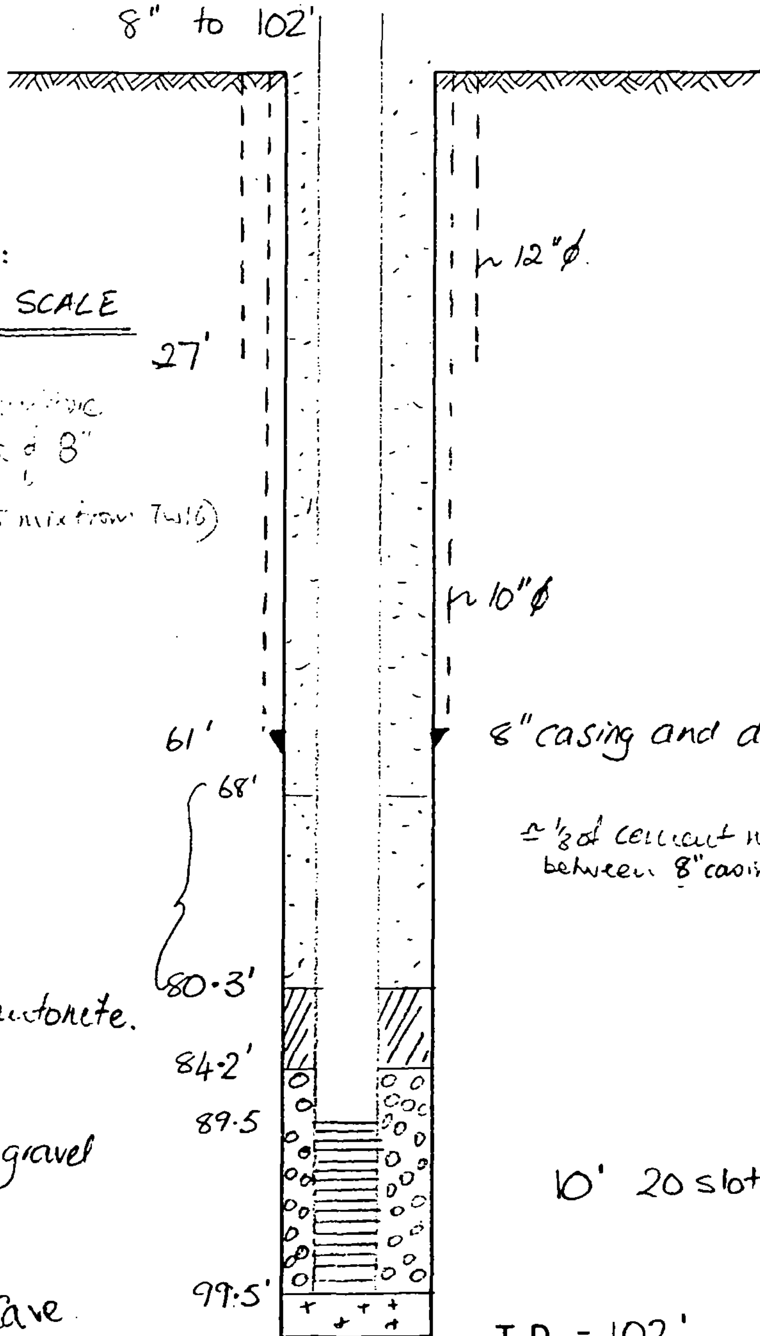
PIEZOMETER INSTALLATION DATA | Figure

BOREHOLE TW 12

HOLE DIAMETER 12" to 27'
10" to 60'
8" to 102'

REMARKS:

NOT TO SCALE



PROJECT NO. .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

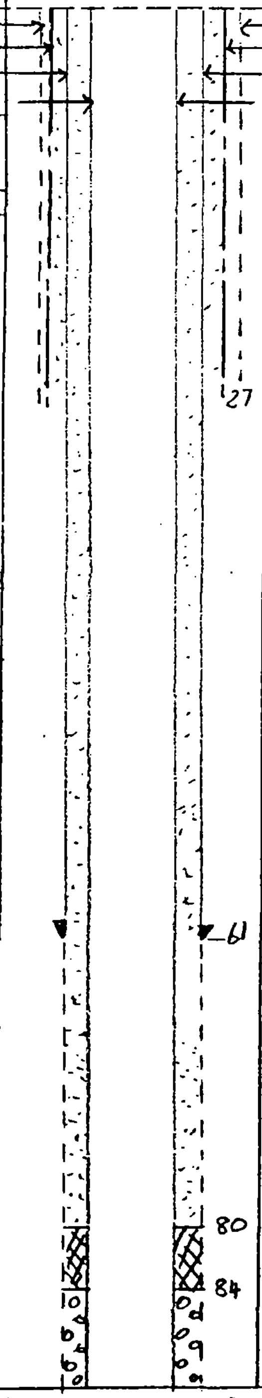
DRILLHOLE No. TW 12
Sheet 1 of 2

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing .... °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ USgpm	(6) Other Pen. Rate mins/ft	After ~~Drilling~~ ~~(2)(7) Water Level (m)~~ T °C	~~Permeability~~ (8) ~~(2) Depth (m)~~ C	~~Method~~ pH	~~Value (cm/s)~~ eH	Comments
Ground Surface										
0–7.0 brown silty CLAY trace gravel										
7.0–12.0 fresh grey vesicular BASALT										
12.0–13.5 ~~red/brown SAND~~					1.2					
13.5–37.0 Fresh grey BASALT with thin sandy zones (24-26 FT., 30-31 FT)					1.0					
					2.0					
					2.1					
					2.0					
37.0–42.5 red/brown sl. to mod weathered BASALT some sand					1.4					
42.5–54 Fresh grey BASALT					2.6					
					4.0					
54–60 rust/brown SILT (weathered cinders?)					1.2					
60–67 red/brown, sl. to mod. weathered BASALT trace clay					1.6					
67–89 Fresh grey BASALT		68	...	1-5	3.0					
					3.0					
					3.0					
					3.6	14.5	–	7.37		
						13	1500	8.05		
89					2.7					

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling
Date started: 31st August 1984
Date finished: 14th Sept. 1984
Logged by: DB/MS.
Checked by: D.B
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW12
Sheet 2 of 2

Project ....

Type of drilling ....

Rig ....

Drilling fluid ....

Coordinates E ....

N ....

Angle from horizontal ....

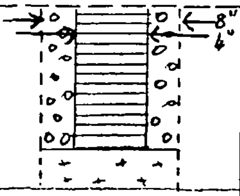
Bearing ....°Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	During Drilling (2)(4) Water Level ~~(m)~~	During Drilling (5) Water ~~Flow (l/s)~~	During Drilling (6) Other Pen. Rate	~~After Drilling (2)(7) Water Level (m)~~	Permeability (8) (2) Depth ~~(m)~~	Permeability (8) ~~Method~~	Permeability (8) ~~Value (cm/s)~~	Comments
Contd		ft	ft	USgpm	mins/ft	T°C	C	pH	eH	
St. weathered rust/brown, loose scoriacious BASALT and CINDERS						10	1450	7.97		
					2.7	10	1500	7.79		
100 — 100										
Fresh grey BASALT 102					2.8	12	1525	7.87		
End of Borehole										
110.										

Contractor: ....
Date started: ....
Date finished: ....

Logged by: ....
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

WELL DEVELOPMENT - TW12

TW12 was developed on September 17th, 1984. One inch pipe was set at 80 ft and the well airlifted at approximately 10 to 15 USgpm. Below is a summary of chemical parameters measured during development.

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	Eh (mV)
5	9	1450	8.16	+167
15	9	1450	7.72	+152
30	9	1450	7.82	+143
45	9	1425	7.71	+133
60	9.5	1450	7.73	+141

Monsanto took a raw water sample following 30 minutes of development. The water was clear during nearly all of the development. The water level in TW11 did not change during well development.

HISTORY OF HOLE

TW12

GEOLOGIST: D. Banton / M. Shaleen DATE: 08/31/84

2:00	Start drilling 10"Ø open hole - drilled to 30' by 3:00 hrs. Run 28' 8" casing.
4:00	Run 8" bit drilled to 67' by 5:45. Hole dry.

DATE: 09/04/84

9:40	Start drilling - making water at 68'. Drilled to 102' by 11:40 - encountered caving cinder/rust weathered basalt 89' to 102'.
12:30	Run geophysical gamma log - hole blocked at 54'.
1:00 - 1:40	Redrill out hole to remove blockage.
1:40 - 2:00	Run gamma log to 88' - blocked beyond - cinder zone caved.
2:00 - 2:40	Run rods - redrill hole to 102' - no return of cuttings - maybe washing into caving zone above 88' thinks driller. Appears material is falling back on top of the bit - pull rods.
2:40	Hole sounded - blocked at 45'. Run rods to 65' to try to remove blockage. Blockage appears thin - further cave noted at 65 to 70'.
4:20	Sounded hole - blocked at 44'. Redrilled to 70' - sounded - blocked at 44'. Appears wet, maybe shallow seepage.

HISTORY OF HOLE

TW12

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/12/84

Moved back onto hole and pulled 8" casing.

3:45 - 4:45 Drilled 12"Ø to approximately 16' - hole caving and drill stem being deflected by rocks falling in hole. 10" casing set to 16'.

DATE: 09/13/84

Drilling 10"Ø to approximately 24' - 10" casing not seated well and pulled out. Drilled 12"Ø to 27' and set 10" pipe to 27'. Drilled 10"Ø 27' to 60' - hole caving and material falling in behind the bit. No return. Add foam - no return. Weld drive shoe to 8" casing - run 8" casing to 55'.

DATE: 09/14/84

Drove 8" casing to 61' - drilled out cave in 8" casing 55 to 60'. Continued drilling at 8"Ø to 100' - no cave.

9:50 - 11:30 Set PVC pipe 5x20' lengths + 1x10' screen at bottom of hole. Gravel packed to 84' with pea gravel. Set 4' bentonite seal.

11:30 - 4:30 Run tremie pipt to 60'. Mix grout - 100 gals water; 17 bags cement; 20 lbs bentonite; 5 to 10 lbs Flocele. Pump about 2/3 of mixture down outsdie PVC. Pump remainder between 8" and 10" casing.

4:30 - 5:30 Pull 10" casing. Try to sound cement outside 8" casing. Could not locate cement. Sounded slurry to 20.94 m (68.7') inside 8" pipe.

TW 13

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA

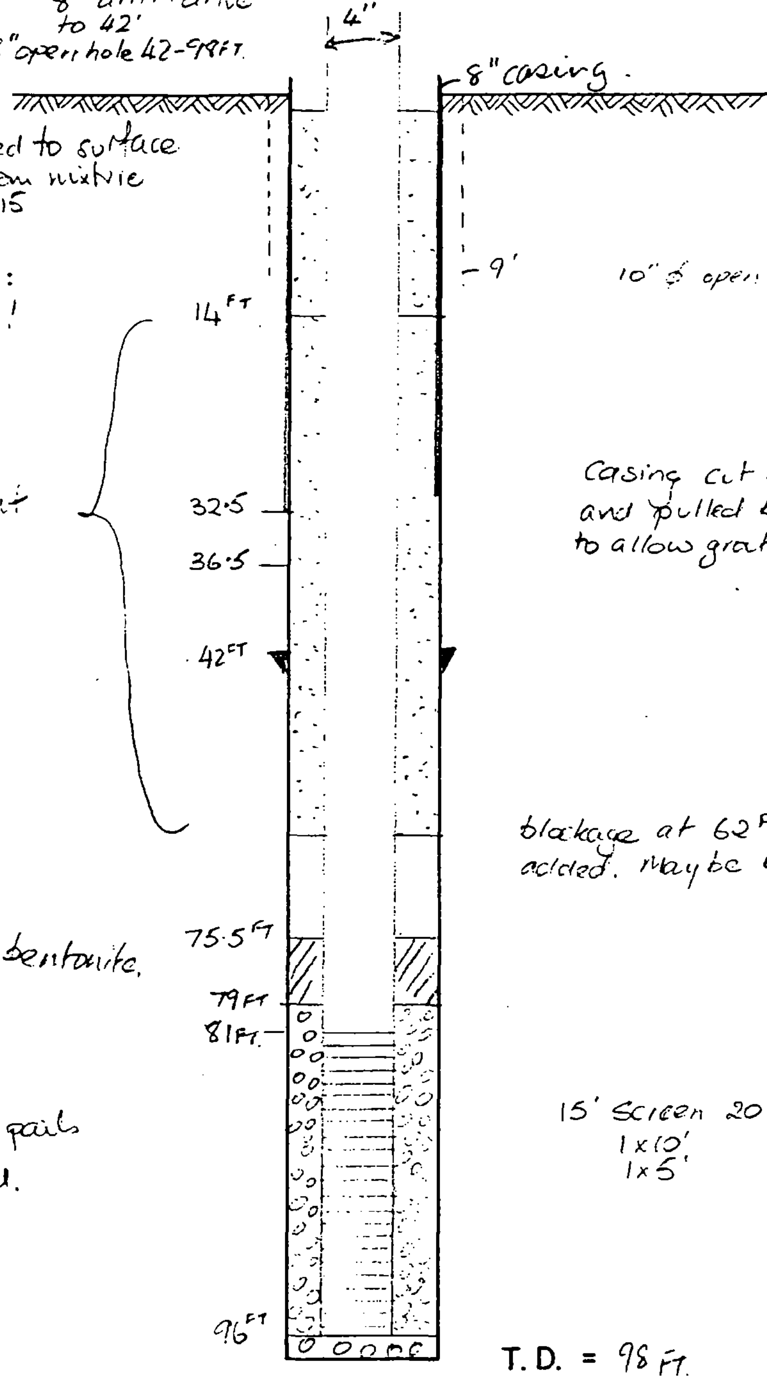
Figure

BOREHOLE TW 13

HOLE DIAMETER 10" open hole to 9'
8" drill + drive
to 42'
8" open hole 42-98FT.

Grouted to surface
with grout from mixture
for TW 15

REMARKS:
NOT TO SCALE!



10" ø open hole to 9'

Grout
20 sacks cement
100 gals water
bentonite
flocele.

Casing cut at 36.5FT
and pulled back to 32.5FT
to allow grout to seal in clay.

blockage at 62FT before grout
added. Maybe bentonite.

4x 20lb pails of bentonite.

8 x 5gallon pails
Pea gravel.

15' Screen 20Slot.
1x10'
1x5'

T.D. = 98 FT.

DATE
REVIEWED
DRAWN
PROJECT NO.

HYDROGEOLOGIC LOG

DRILLHOLE No. TW13
Sheet 1 of 2

Job No.

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E ....
N ....
Angle from horizontal: 90°
Bearing: .... °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL.

Depth (ft)	(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	During Drilling (2)(4) Water Level ~~(m)~~ ft	During Drilling (5) Water Flow ~~(L/s)~~ USgpm	During Drilling (6) Other Pen. Rate mins/ft	After ~~Drilling~~ (2)(7) Water ~~Level (m)~~ T	~~Permeability (8)~~ (2) ~~Depth (m)~~ C	~~Permeability (8)~~ Method pH	~~Permeability (8)~~ ~~Value (cm/s)~~ eH	Comments
0	Ground Surface										
0–12	Silty SAND and GRAVEL	8" ; 6"									
12–22	pale brown sandy GRAVEL										
22			22	9.5	10-20		12	550	6.90	+165	Water sample from 22 ft F = 0.41 mg/l
22–42	red brown silty CLAY to gravelly CLAY	32 ; 36									Casing cut at 36' and pulled back 4' to allow grout to seal in clay.
40–42		42	40	12.0			8	575	7.61	+192	
			43	11.8							
42–73	fresh grey BASALT					3.8	9	575	7.76	+121	Water sample from 45 ft F = 0.32 mg/l.
						4.4	9	600	7.91	+164	
						3.0	9	600	7.82	+102	
						3.6	9.5	600	7.74	+120	
						5.6	10	575	7.91	+146	
70					30-50	4.6					
73–90	pale brown silty CONGLOMERATE	75 ; 79				1.0	10	600	7.55	+156	
						1.0	12	600	6.85	+192	
						1.0	13	600	6.30	+175	

Contractor: Andrew Well Drilling.
Date started: 17th Sept 1984
Date finished: 19th Sept 1984

Logged by: DB/MS
Checked by: ....
Date ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW13
Sheet 2 of 2

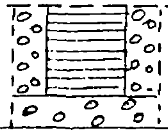
Project MONSANTO GROUNDWATER STUDY

Type of drilling ....
Rig ....
Drilling fluid ....

Coordinates: E ....
N ....
Angle from horizontal ....
Bearing ....° Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ....

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(L/s)~~ USgpm	(6) Other Pen Rate	After ~~Drilling~~ (2)(7) ~~Water Level (m)~~ T	~~Permeability (8)~~ ~~(2) Depth (m)~~ C	~~Method~~ pH	~~Value (cm/s)~~ eH	Comments
Cont'd										
pale brown silty CONGLOMERATE 98	 96				1.0	12	600	7.47	+191	
					1.3	12	600	7.6	—	
100 End of Borehole										

Contractor ....
Date started ....
Date finished ....

Logged by ....
Checked by ....
Date ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW13

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/17/84

5:00 p.m. Began drilling. Drilled 8"Ø open hole to 22' - caving from saturated sand and gravel. Picked up 8" casing and drove casing to 40' by 8:00 p.m.

DATE: 09/18/84

DTW at start of shift = 14' ftom top of casing. Bedrock at 42' - drove casing firmly into rock. Water saples at 22' F=0.41 mg/l; 45' F=0.32 mg/l.

9:00 - 12:00 Drilled open hole 42' to 98'. Basalt at 42' to 73'. Conglomerate at 73' to 98'. Most water appears to be made in upper 15' of fractured basalt.

2:15 - 3:15 Logged well with gamma and resistivity.

3:30 Ran casing cutter to 36' and cut off drive shoe.

3:45 - 6:30 Set 15' 20 slot screen and 5x20' blank PVC at bottom of hole - cut off 18' blank PVC at surface. Gravel packed to 79' (2' above screen) 8x5 gal pails gravel. Placed 4' bentonite seal above gravel (80 lbs bentonite pellets).

DATE: 09/19/84

Ran 1" tremie pipe to 60' - hole appears blocked by bentonite at 62'.

7:00 - 10:45 Mix cement slurry. 20 sacks cement in 100 gals water, added bentonite and Flocele.

10:45 - 11:30 Pump slurry into hole.

11:30 - 12:15 Pull 8" casing 4' to expose slurry to clay layer and prevent seepage of water from sandy gravel entering basalt. 32.5' of 8" casing left in TW13 + shoe. Sounded grout to 14.4' below surface on September 20. Grouted to surface on evening of September 20.

WELL DEVELOPMENT - TW13

TW13 was developed on October 8th using compressed air. One inch diameter pipe was set to 60 ft below ground level. The well was developed for approximately 70 mins at a rate of about 10 gpm. The water remained clear during development.

Chemical parameters recorded during development are tabulated below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	Eh (mV)
0.5	12	650	7.50	+202
20	10.5	626	7.80	+198
35	9	600	7.83	+208
55	9	625	7.76	-
68	9	600	7.76	-*

*Sampled for Monsanto

F = 0.25 mg/l

The water level in TW15 had not fully recovered to original static when TW13 was developed; however, TW15 drew down 0.07 ft during the development of TW13. Full recovery of TW15 was observed approximately 6 hrs later. The water level in TW14 did not respond to the development of TW13.

TW 14

i) Schematic Test Well Completion

ii) Field Borehole Log

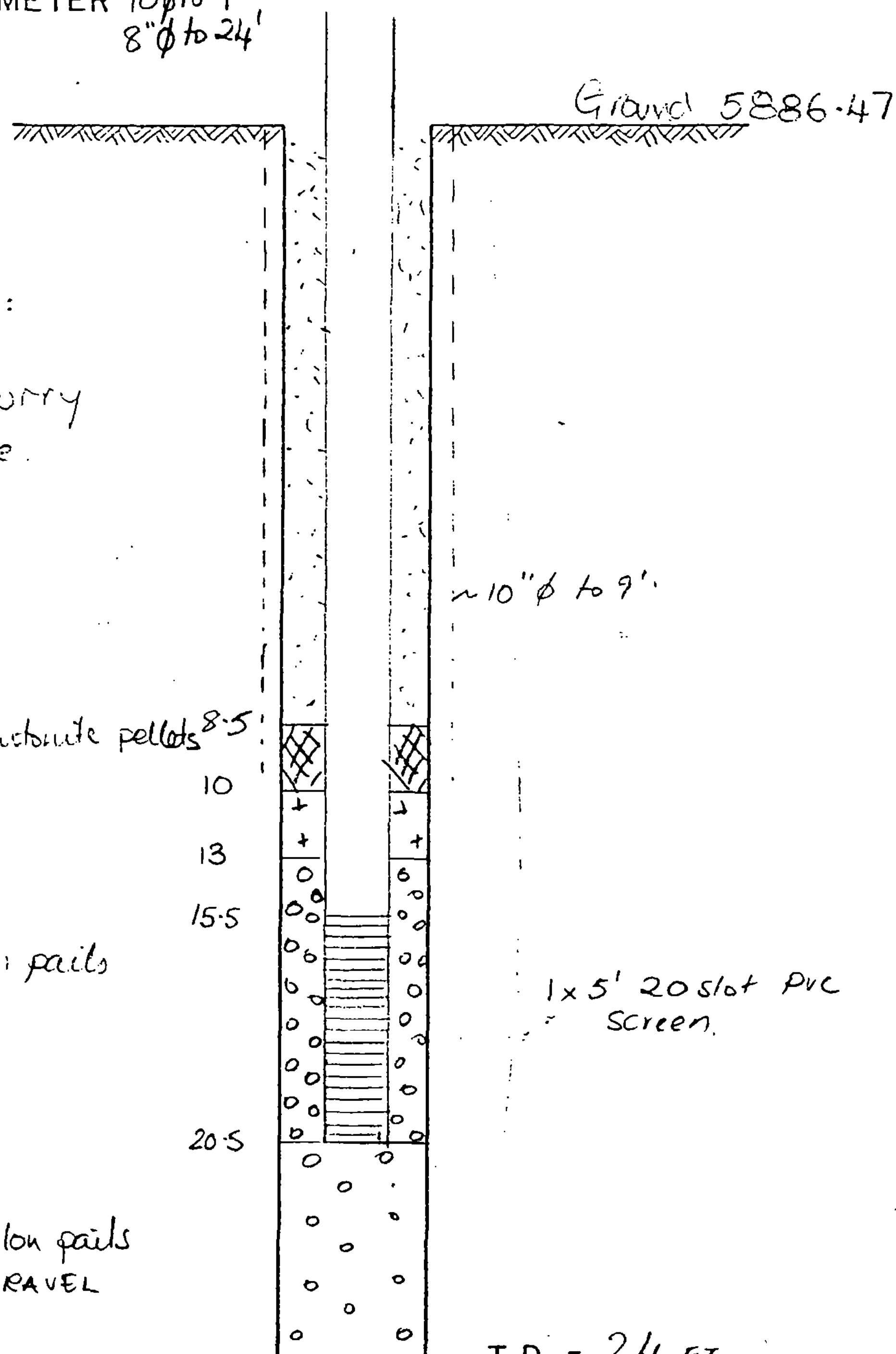
iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA

Figure

BOREHOLE TW 14

HOLE DIAMETER 10"ø to 9'
8"ø to 24'



REMARKS:

Cement slurry to surface.

60 lbs bentonite pellets

Cave

6 x 5 gallon pails Gravel.

2½ x 5 gallon pails GRAVEL

T.D. = 24 FT

PROJECT NO. 843-1028A DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW 14
Sheet 1 of 1

Project MONSANTO GROUNDWATER STUDY
Type of drilling ROTARY
Rig SCHRAMM T-64
Drilling fluid AIR/WATER

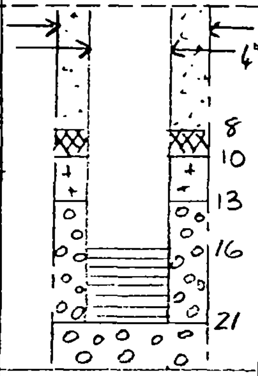
Coordinates: E
N
Angle from horizontal 90°
Bearing °Azimuth

Reference elevation 5886.47
Elevation type: surveyed ☑ altimeter ☐ from map ☐
Purpose of hole MONITORING WELL.

Job No.

Re-draw at 1:100 Imperial

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2)(4) Water Level ~~(m)~~	(5) Water Flow ~~(l/s)~~	(6) Other	After Drilling (2)(7) Water Level (m)	Permeability (8) (2) Depth (m)	Method	Value (cm/s)	Comments
Ground Surface		ft	ft	Usgpm		T	C	PH	EH	
Silty SAND and GRAVEL	3" 6" 8									
10 11	10	9	m.w.							
pale brown sandy GRAVEL	13 16	15		5-10		14	600	7.58	—	
20 21	21									
red/brown silty CLAY 24										
End of Borehole										
30										



Contractor: Andrew Well Drilling
Date started: 19 Sept 1984
Date finished: 19 Sept 1984
Logged by: DB/MS
Checked by:
Date:

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW14

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/19/84

1:15 - 1:30	Move and set up on TW14.
1:30 - 4:00	Drill and drive 8" casing with drive shoe to 24' below ground. Encounter water at 9'. Drilled about 3' into clay. (First 9' of hole drilled 10"Ø open hole.)
4:00 - 6:30	Set 1x5' 20 slot PVC screen + 1x20' PVC blank pipe at 20.5'. Gravel pack screen with 6x5 gal pails of gravel to 13'. Caved materials 13' to 10'. 60 lbs bentonite above cave to 8.5'. Hole grouted to surface with cement slurry on September 20. 8" casing and drive shoe pulled out.

WELL DEVELOPMENT - TW14

TW14 was developed on October 8th using compressed air. One inch diameter pipe was set to 18 ft below ground level (inside well screen). The well was developed for approximately 50 mins and airlifted approximately 20 gpm. The water was initially milky; however, it cleared up after about 5 mins of development.

Chemical parameters recorded during development are tabulated below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	Eh (mV)
1	11.5	600	7.81	+232
22	11.5	590	7.65	+213
37	11.5	600	7.70	+219
52	10	600	7.71	+220*

*Sampled for Monsanto

F = 0.35 mg/1

No response to development was seen in either TW13 or TW15.

The water level in TW14 recovered to within 0.06 ft of original static water level within 5 mins of development ending.

WELL DEVELOPMENT - TW14

The well was bailed on October 27th using an 8-1/2 ft long, 2 in. diameter PVC bailer with a check valve (brass). The well was bailed 10 times, removing approximately 13.5 gals from the well. Well volume at the time of bailing was 7.2 gals. The sample was cloudy due to suspended silt. The sample was taken to the Monsanto laboratory for immediate filtering and preservation.

Field measurements for temperature, conductivity and pH are given below:

T = 6°C

C = 575 μmhos/cm

pH = 7.08 (Monsanto lab = 7.40)

Prior to bailing, the brass check valve of the bailer was lost into the well. The check valve has not been retrieved.

TW 15

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

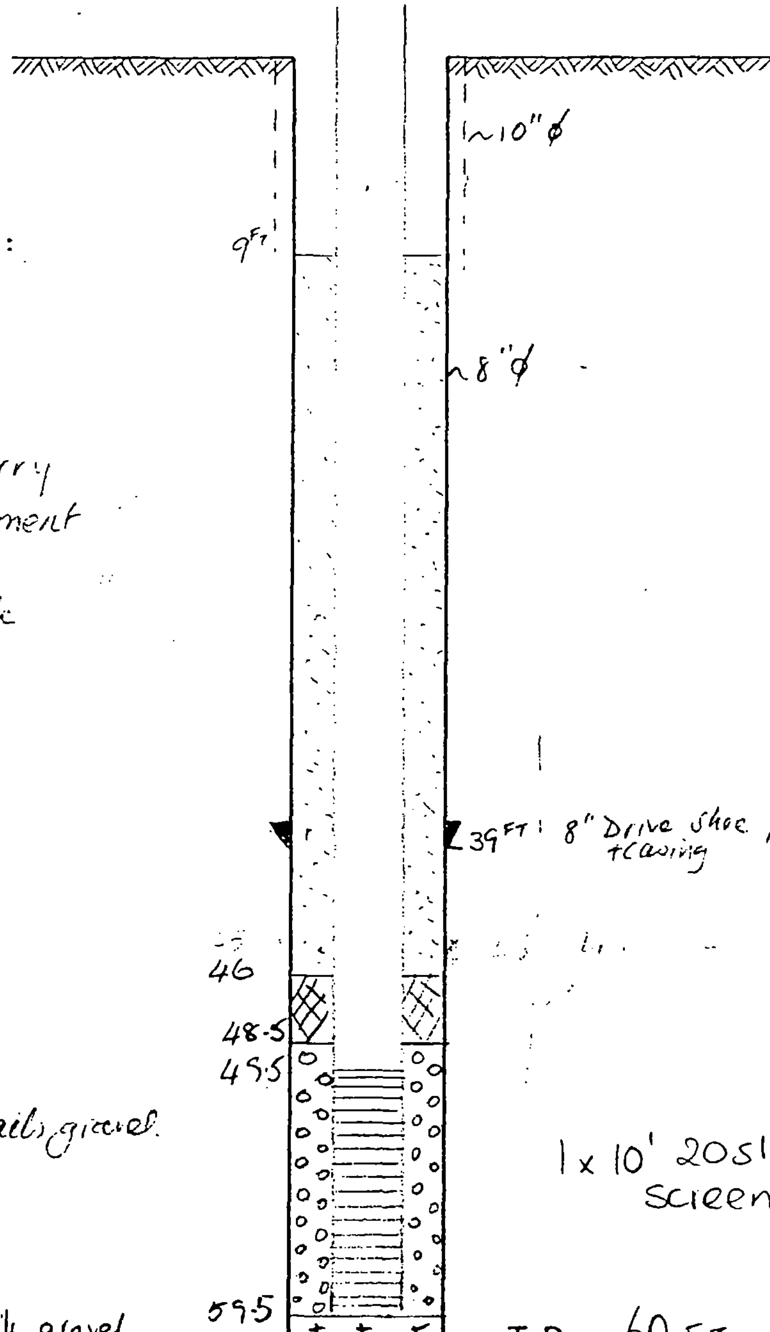
PIEZOMETER INSTALLATION DATA

Figure

BOREHOLE TW 15

HOLE DIAMETER 10" to 9'
8" to 60 FT

REMARKS:



Cement slurry
23 bags cement
125 gals H_2O
15 lbs flocele

39 FT: 8" Drive shoe pulled back to 39 FT + casing

80 lbs bentonite

16 x 2 gallon pails gravel

1 x 10' 20 slot PVC screen

2 x 2 gallon pails gravel

T.D. = 60 FT

PROJECT NO. .... DRAWN .... REVIEWED .... DATE

Golder Associates

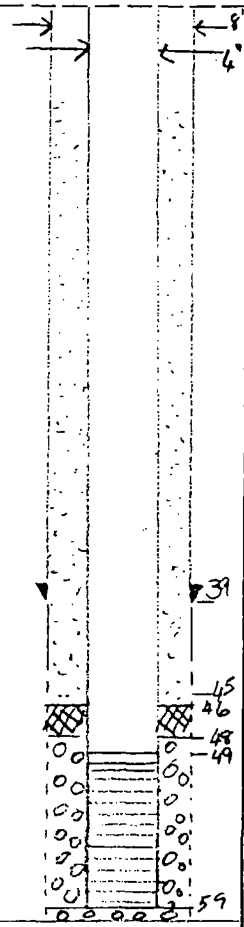
HYDROGEOLOGIC LOG

DRILLHOLE No. TW15
Sheet 1 of 1

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-66
Drilling fluid: AIR/WATER
Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth
Reference elevation: ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

Redraw at 1:100 [illegible]

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~	During Drilling: (2)(4) Water Level ~~(m)~~	During Drilling: (5) Water Flow ~~(L/s)~~	During Drilling: (6) Other	After Drilling: (2)(7) Water Level (m)	Permeability: (2) Depth (m)	Permeability: Method	Permeability: (8) Value (cm/s)	Comments
Ground Surface		ft	ft	[illegible]						
Silty SAND and GRAVEL (0–12)		9		m.w						No chemical parameters recorded during drilling
pale brown sandy GRAVEL (12–21)										
red/brown silty CLAY to gravelly CLAY (21–45)										
Fresh grey BASALT (fractured) (45–60)		60	11.9	30-50						
End of Borehole										

Depth scale: 10, 20, 30, 40, 50, 60

Contractor: Andrew Well Drilling
Date started: 20th Sept 1984
Date finished: 20th Sept 1984
Logged by: DB/M.S.
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW15

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/20/84

7:45	Set up and start drilling.
7:45 - 8:10	Drilled open hole 10"Ø to 9'.
8:10 - 8:50	Hook up hammer, weld on drive shoe to 8" pipe.
8:50 - 11:10	Drilling with casing to 45' through overburden 8"Ø.
11:10 - 12:30	Drilled 8"Ø open hole to 60' (not supervised). Hole not logged since Monsanto had equipment.
1:45 - 4:45	Set 1x10' PVC 20 slot screen + 3x20' blank PVC. Gravel packed 59 to 48-1/2' with 16x2 gal pails gravel. Bentonite seal 48-1/2 to 46' with 80 lbs bentonite pellets. Added cement slurry via tremie pipe (40' long). Mix - 125 gals water, 23 bags cement, 15 lbs Flocele, trace bentonite. Pulled 8" casing after slurry added. Casing pulled back 6' to allow grout to seal in clay.

WELL DEVELOPMENT - TW15

TW15 was developed on October 8th using compressed air. One inch diameter pipe was set to 40 ft below ground level (inside well screen). The well was developed for approximately 55 mins at a rate of 20 to 30 gpm.

Chemical parameters and water levels recorded in TW13 and TW14 are shown below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	Eh (mV)
5	9.5	400	8.07	+301
20	11	550	7.98	+313
40	10	600	7.78	+242
55	11.5	600	-	-*

*Sampled for Monsanto

F = 0.26 mg/l

The well recovered to within 0.05 ft of original static water level within a few minutes of development ending.

TW13 drew down 0.15 ft during the development of TW15. Full recovery of TW13 was not observed. TW13 recovered approximately 0.1 ft in the 1 hr period following development of TW15.

TW14 showed no response to development of TW15.

WELL DEVELOPMENT - TW15

The well was bailed using the PVC bailer on October 27th, 1984. The well was bailed 50 times, removing 68 gals of water. The well volume at the time of sampling was 31 gals. The water remained clear during bailing. The sample was immediately taken to the Monsanto laboratory for filtering and preservation.

Field measurements:

T = 6.5°C

pH = 7.68 (Monsanto lab = 7.40)

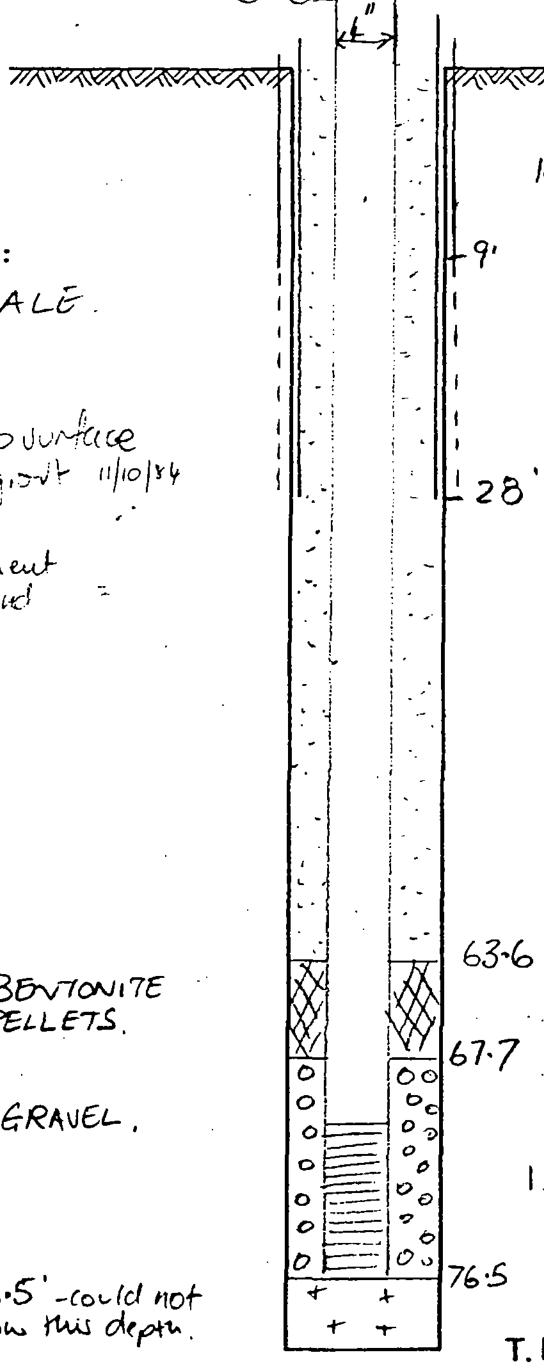
C = 400 μmhos/cm

PIEZOMETER INSTALLATION DATA

Figure

BOREHOLE TW16

HOLE DIAMETER 10" to 28'
8" 28-82'



10" CASING TO 9'.

8" CASING TO 28'

REMARKS:
Not to SCALE.

Cemented to surface with 1½ yards grout 11/10/84
1 yard = 48 gals H_2O
9 bags cement
2200 lbs sand

4"Ø – 3x20' blank PVC
4"Ø – 2x10' blank PVC

3 x 20lb pails BENTONITE PELLETS.

10 x 20lb pails GRAVEL.

1 x 5' screen 20 slot – 4"Ø.

Hole caved to 76.5' - could not be kept open below this depth.

T.D. = 82'

PROJECT NO. .... DRAWN .... REVIEWED .... DATE ....

Golder Associates

TW 16

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

HYDROGEOLOGIC LOG

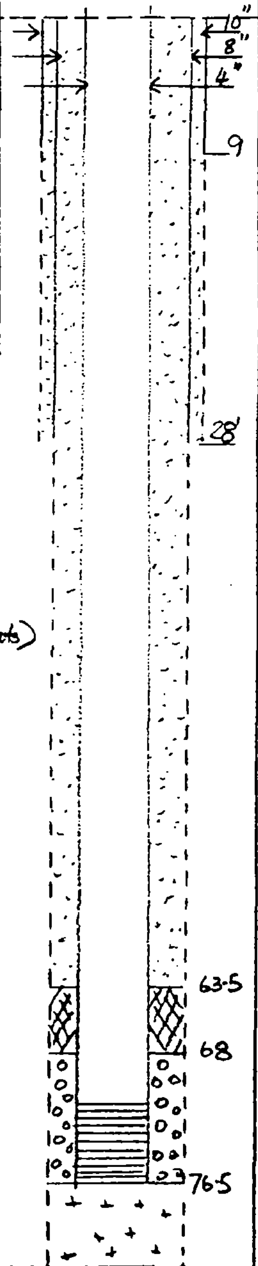
DRILLHOLE No. TW 16
Sheet 1 of 1

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER
Coordinates: E ..... N .....
Angle from horizontal: 90°
Bearing ..... °Azimuth
Reference elevation .....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) ~~Other~~ Pen. Rate min/ft	After Drilling (2)(7) Water Level (m) T °C	Permeability (2) Depth (m) C us/cm	Method pH	(8) Value (cm/s) eH	Comments
Ground Surface										
0–9.0: silty SAND and GRAVEL (FILL)	10", 8", 4"; 9									
9.0–22.0: red/brown silty CLAY trace gravel										
22.0–36.5: Fresh grey BASALT (clay layers 25-25½' and 28-29')	28'				2.4					
36.5–44: red/brown silty SAND (some gravel sized basalt fragments) (weathered Cinders?)					1.0					
					1.0					
44–75: Fresh grey BASALT.					3.0					
					2.0					
					5.4					
	63.5				4.4					
	68	68	mw		8.0					
					6.0					
75–76.5: red/brown loose scoriaceous CINDERS	76.5	76	59.4	20-30	3.0	12	1300	8.01	–	Circulation lost at 77 ft
76.5–82: fresh grey BASALT.										
82: End of Borehole										

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90



Contractor: Andrew Well Drilling
Date started: 21st September 1984
Date finished: 25th September 1984
Logged by: DB/MS
Checked by: .....
Date: .....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW16

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/21/84

7:15 - 8:40	Move and set up on TW16.
9:30 - 9:40	Start drilling 10"Ø drilled to 10'. Set 9'10"Ø casing to stabilize fill.
9:40 - 10:30	Drill 10"Ø open hole to 28' - bedrock 22'.
10:30	Pull out 10" bit, set 8" casing to 28'.
11:40 - 12:55	Drilling 8" open hole from 28' - some cinders/weathered basalt at 36-1/2'. Water at 68' - <1 gpm. 74' making 2 to 5 gpm. 76' - 1/2' cinder zone? Loose drilling circulation at 76-1/2'.
4:00	Drilled to 82' - no return. Pull rods - rods wet below 35' - probably loosing water into cinder zone at this depth.
5:00 - 5:45	Logged hole for gamma only. Water level at 59.4' below ground level.

DATE: 09/25/84

	Move back onto TW16.
8:40 - 10:00	Drilling out cave and stabilizing hole - some cave at 40'.
10:00 - 12:00	Set 1x5' 20 slot screen, gravel pack to 67.7' with 10x2 gal pails gravel. Bentonite pellets to 63.6' 3x20 lb pails.

DATE: 10/11/84

Hole grouted to surface with approximately 1-1/2 yds of grout.

Grout = 48 gals water/yd
= 9 bags cement/yd
= 2200 lbs sand/yd

Grout poured from surface.

WELL DEVELOPMENT - TW16

TW16 was developed on September 29th. Tremie pipe was set to 75 ft. Developed for 35 mins at a rate of 10 to 15 gpm. The water was red/brown for the first 5 mins of development and then cleared up.

Chemical parameters and water levels recorded during development are shown below:

Elapsed Time (mins)	T °C	C (µmho/cm)	pH	Depth to Water Level (TOC) (m) TW17	TW18
Before				18.88	
2	11	1150	7.66	18.885	17.91
15	10	1100	7.80	18.89	
25	9	1100	7.84		*
35	9	1150	7.88	18.89	*
After				18.88	*

*Recovering from development

The well recovered instantaneously. A water sample was taken for further analysis by Monsanto.

Fluoride Measurement = 7.4 mg/l

<u>TW 17</u>

i) Schematic Test Well Completion

ii) Field Borehole Log

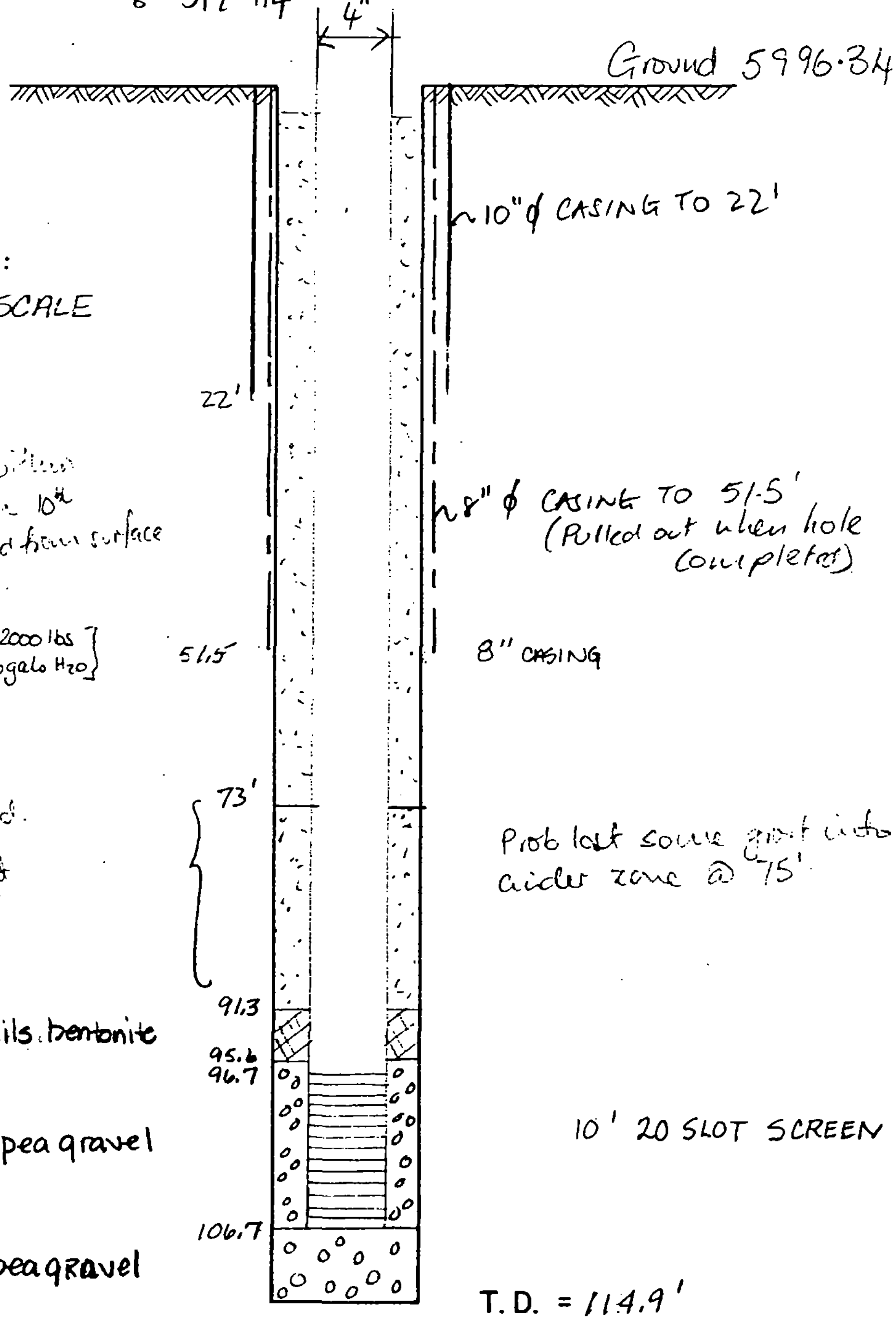
iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA	Figure

BOREHOLE TW17

HOLE DIAMETER 10" 0-51½'
8" 51½-114'

REMARKS:
NOT TO SCALE



Grouted to within 8' of surface on 10th + 14th Oct. Poured from surface ± 1½ yards grout.
[12 bags cement + 2000 lbs sand per yard 48 gals H_2O]

Grout pumped. 125 gals H_2O 21 bags cement trace bentonite floccle.

3x20 lb pails bentonite

6 pails pea gravel

5.5 pails pea gravel

PAILS = 40 gallons

DRAWN .... REVIEWED .... DATE

PROJECT NO.

HYDROGEOLOGIC LOG

DRILLHOLE No. TW 17
Sheet 1 of 2

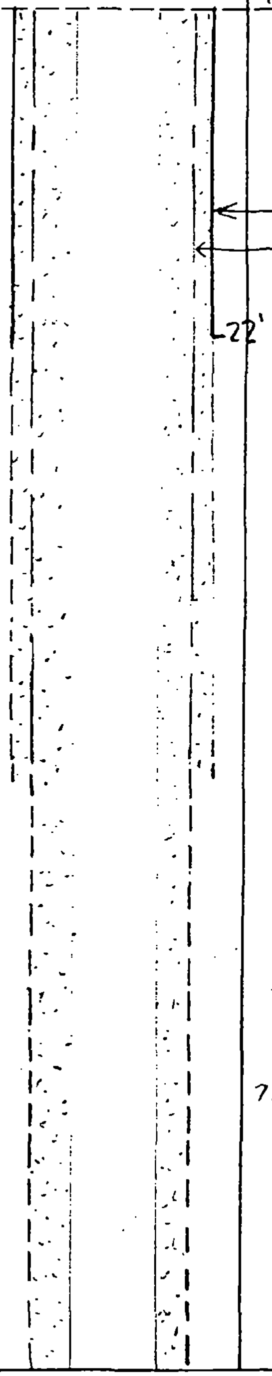
Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing .... °Azimuth

Reference elevation: 5596.34
Elevation type: surveyed ☑ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No. ....

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2) (4) Water Level ~~(m)~~	(5) Water Flow ~~(L/s)~~	(6) Other Pen. Rate	After Drilling (2) (7) Water Level ~~(m)~~	Permeability (8) (2) Depth (m)	Method	Value (cm/s)	Comments
GROUND SURFACE		ft.	~~ft~~	gpm	min/ft	T°c	C umhos/cm	pH	eH mV	
Silty SAND AND GRAVEL (FILL) 6										
10' Brown silty CLAY trace gravel	10" / 8"									
22 Fresh grey BASALT	22'									
30										
35.5 Redish brown silty SAND and GRAVEL (weathered cinders?) becoming denser below 46'										
40										
50 50										
					1.5					
60					3.4					
FRESH GREY BASALT					4.4					
70					5.6					70
		72		mw	4.4					
76.5 / 78					2.8	11°	1300	7.45	+139	
80 Fresh grey BASALT					3.0	10°	1250	7.62	+109	80
					4.4	9°	1200	7.60	+64	
90										



brown ~ scoriaceous cinders

Contractor: ANDREW WELL DRILLING
Logged by: DB/MS
Date started: 21st SEPTEMBER 1984
Checked by: ....
Date finished: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW17
Sheet 2 of 2

Project ....
Type of drilling .... Coordinates: E ....
N ....
Rig ....
Drilling fluid .... Angle from horizontal ....
Bearing .... °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ....

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2) (4) Water Level ~~(m)~~	(5) Water Flow ~~(l/s)~~	(6) Other PEN. RATE	After Drilling (2) (7) Water Level ~~(m)~~	Permeability (8) (2) Depth (m)	Method	Value (cm/s)	Comments
CONT'D		ft	ft	USgpm	mins/ft	T °C	C umho/cm	pH	eH mV	
Fresh grey BASALT	91 – 95.5				2.4	9°	1200	7.56	+63	
* faintly weathered vesicular BASALT 98 – 99					4.0	9°	1200	7.60	+68	
100 Fresh grey BASALT 99 – 102					2.4	9°	1200	7.52	—	
Reddish brown, faintly weathered vesicular BASALT 102 – 107	104.5				2.4	9°	1200	7.54	91	
110 Fresh grey BASALT										Circulation lost @ 108 ft
115	115				3.6					
END OF HOLE										

Contractor .... Logged by: ....
Date started: .... Checked by: ....
Date finished: .... Date: ....

\# NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW17

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/21/84

4:15 - 4:30	Move and set up on TW17
4:30 - 5:15	Drill to 22' (bedrock) set to 10'10" casing to stabilize fill.
5:50 - 7:00	Drilling open hole 10"Ø to 47' - hole starts to cave at 45' in weathered basalt/cinders (no water).

DATE: 09/22/84

8:00	Start drilling. Drilled to 52' by 8:20 - out of caving material into more competent basalt.
8:20 - 9:30	Pull rods - set 8"Ø casing to 50'. Rerun rods.
9:30 - 1:35	Drilling 8"Ø open hole 52 to 113'. Water at 68' <1 gpm. Pick up more water at 76-1/2 to 78' - cinder zone? Water sample for Monsanto - F = 9.7 mg/l. Vesicular/weathered basalt 102 to 107' - more water. Loose circulation of cuttings and water at 108'.
1:35	Pull drill rods - push 8" casing to 51-1/2' below ground. Rerun rods.
2:10	Restart drilling - no return.
2:15	Pull rods.
2:30 - 3:15	Log hole for gamma and resistivity. DTW = 59.2' below ground level.

HISTORY OF HOLE

TW17

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/24/84

9:30 - 12:55	Backfill hole to 106.7' with gravel 5-1/2x4 gal pails. Set 1x10' 20 slot PVC screen and 110' blank PVC 4"Ø. Gravel pack screen to 95.6' 6x4 gal pails. Bentonite to 91.3' 3x20 lb pails.
1:50 - 7:00	Run tremie pipe to 80'. Mix grout 125 gals water; 21 bags cement; Flocele; trace bentonite. Pump grout, pull tremie and clean up.

DATE: 09/25/84

Depth to top of grout sounded as 72.8' (probably invaded upper cinder zone at 76').

DATE: 10/04/84

Hole grouted to surface with 9 bag grout and sand, approximate volume = 1-1/2 yds.

WELL DEVELOPMENT - TW17

TW17 was developed with compressed air on September 29th. One inch diameter Tremie pipe set to 80 ft. The well was developed for 35 mins at a rate of 2 to 5 gpm. The water was clear at all times during development.

Chemical parameters and water levels recorded during development are shown below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	Depth to Water Level (TOC) (m)	
				TW16	TW18
0				18.90	
5	9	1350	8.24	18.90	17.96
15	7.5	1350	8.37		
25	7.5	1350	8.39	18.90	17.945
35	8	1350	8.42		*

*Recovering from development

The well had fully recovered within 10 mins of development ending.

A water sample was taken for Monsanto after 35 mins of develop- ing.

Fluoride Measurement = 7.9 mg/1

TW 18

i) Schematic Test Well Completion

ii) Field Borehole Log

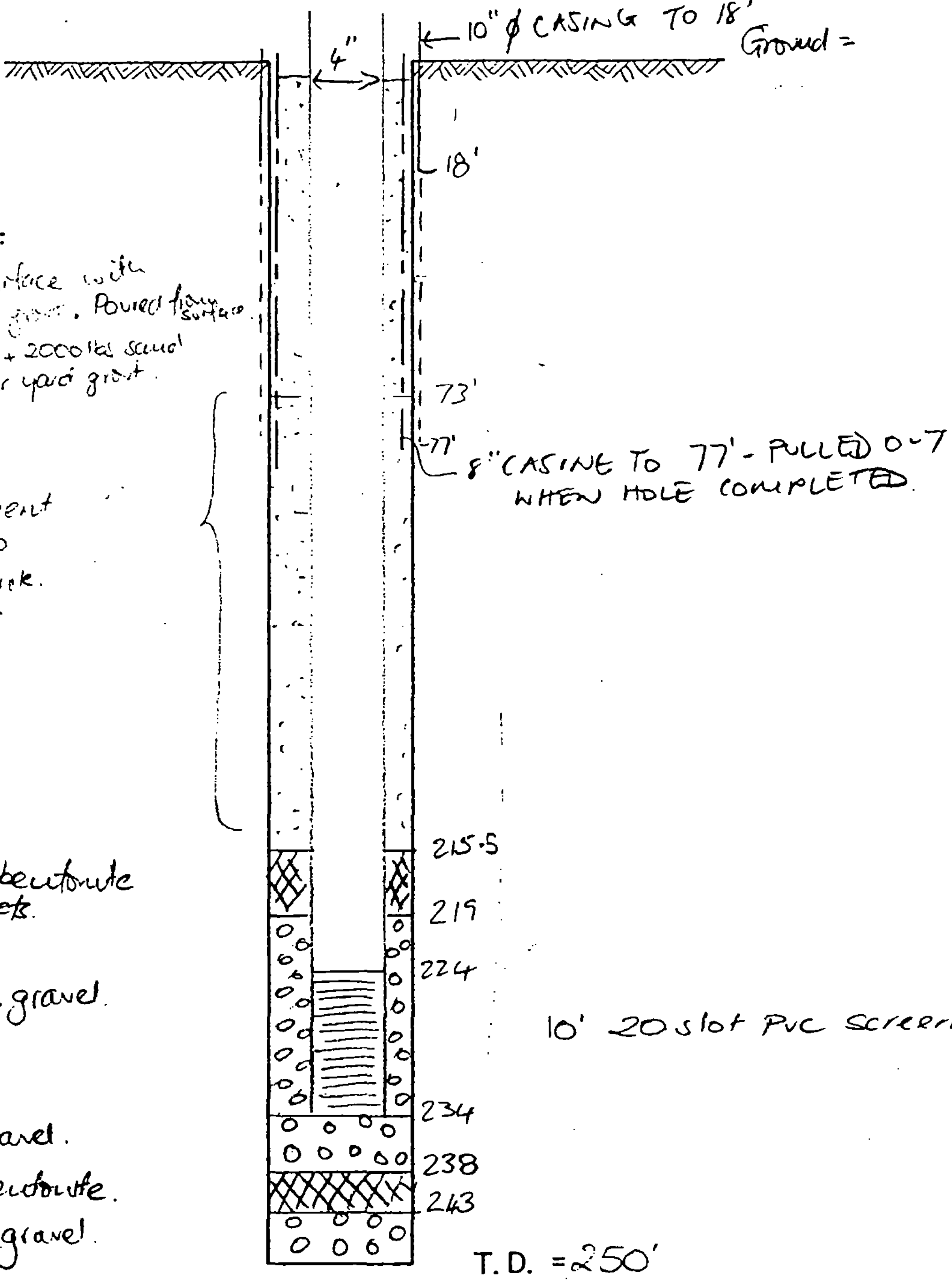
iii) History of Hole and Well Development

~~PIEZO~~METER INSTALLATION DATA
WELL

Figure

BOREHOLE TW18

HOLE DIAMETER 10" to 77'
8" 77 – 250'



REMARKS:

Grouted to surface with approx 2 yards grout. Poured from surface
12 bags cement + 2000 lbs sand
+48 gals H_2O per yard grout.

73 bags cement
400 gals H_2O
100 lb bentonite
25 lb flocele

3x20lb pails bentonite pellets.

15x20lb pails gravel.

6x20 lb pails gravel.
4x20lb pails bentonite.
13x20lb pails gravel.

DATE .... REVIEWED .... DRAWN .... PROJ. NO. ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW18
Sheet 1 of 3

Project: MONSANTO GROUNDWATER STUDY

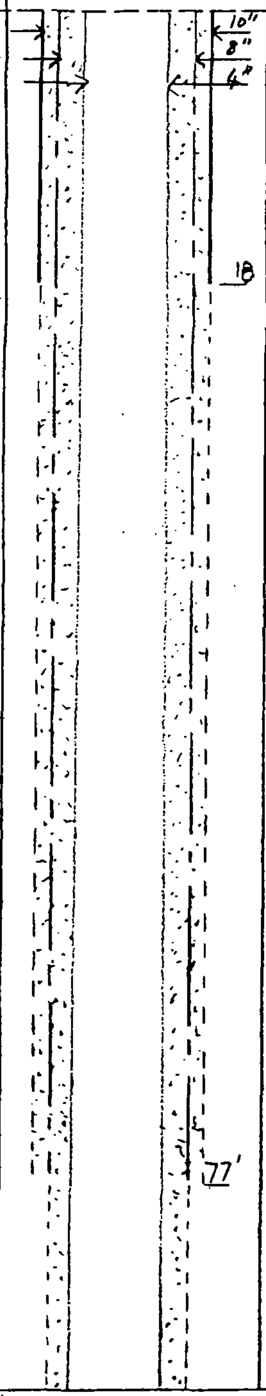
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation: ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) Other Pen Rate min/ft	After Drilling: (2)(7) ~~Water Level (m)~~ T °C	~~Permeability~~ (8): (2) ~~Depth (m)~~ C µs/cm	~~Method~~ pH	~~Value (cm/s)~~ eH	Comments
Ground Surface.										
silty SAND and GRAVEL (FILL) 3.0	10" 8" 4"									
red/brown silty 10 CLAY. 19.0	18									
20 Fresh grey BASALT (sand horizon 29-30')										
30					2.6					
34.5					2.6					
Red brown silty SAND to silty 40 GRAVEL (some basalt fragments) (Weathered cinders?)					1.4					
46.5					4.0					
50 Fresh grey BASALT					3.0					
					3.0					
60					8.0					
		66		m.w	5.0					
70					4.0					
74 red/brown loose scoriacious cinders 76	77'	75	58.2	20-30	3.0					Caving at 77'
80 Fresh grey BASALT.		82			3.2	7.5	1050	7.4	+105	
		87			6.4	6.5	1000	7.52	+136	
90					6.0					



Contractor: Andrew Well Drilling
Date started: 25th September 1984
Date finished: 28th September 1984

Logged by: DB/MS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale: —

HYDROGEOLOGIC LOG

DRILLHOLE No. TW18
Sheet 2 of 3

Project ....

Type of drilling .... Coordinates: E ....

Rig .... N ....

Drilling fluid .... Angle from horizontal ....

Bearing .... °Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

Job No.

(1) (2) * Lithology

Cont'd
Fresh grey basalt. 92
92–93
93 Fresh grey BASALT 98
100 Faintly weathered red/brown vesicular BASALT. 105
110
Fresh grey BASALT
120
130
140
150
160
168
168–170 Grey/green CLAY 170
170
Fresh grey BASALT
180

(2) (3) Completed Construction

8" → 4"

During Drilling: (2) Depth (m) ft	(2)(4) Water Level (m) ft	(5) Water Flow (L/s) gpm	(6) Other Pen. Rate mins/ft	After Drilling: (2)(7) Water Level (m) T	Permeability (8): (2) Depth (m) C	Method pH	Value (cm/s) eH	Comments
92			6.0	6.5	1000	7.52	+136	
			3.6					
97				7.5	1025	7.57	+42	
			2.0					
103				7	1050	7.61	+83	
			3.0					
107				7	1000	7.71	+39	
			4.0					
112				7.5	1025	7.58	+169	
			4.0					
117				7.5	1025	7.73	+62	
			6.0					
122				8	1025	7.69	+173	
			6.0					
127				8	1025	7.78	+104	
			5.4					
132				8	1050	7.77	+177	
			5.0					
137				8	1025	7.72	+97	
			4.0					
142				8	1050	7.62	+169	
			3.0					
147				8	1050	7.68	+113	
			5.0					
152				8	1050	7.70	+96	
			5.0					
157				8	1050	7.66	+105	
			5.0					
162				7.5	1000	7.65	+174	
			5.0					
167				6.5	1000	7.39	+126	
			4.4					
172				6.5	1000	7.46	—	
			4.4					
177				6	1000	7.56	+118	
			7.0					

Contractor .... Logged by: ....

Date started: .... Checked by: ....

Date finished: .... Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW18
Sheet 3 of 3

Project ....

Type of drilling ....

Rig ....

Drilling fluid ....

Coordinates: E ....

N ....

Angle from horizontal ....

Bearing .... ° Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

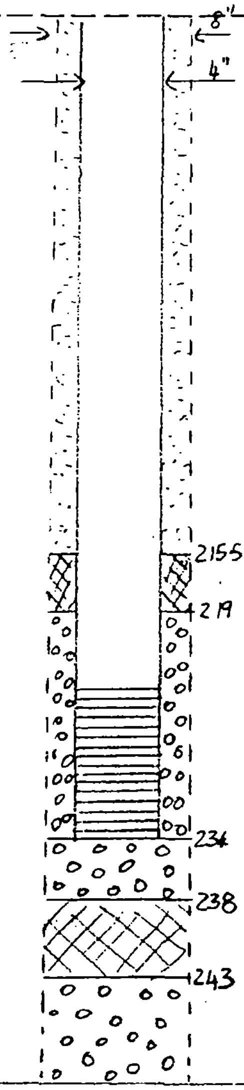
Purpose of hole ....

Job No.

(1) (2) * Lithology (Cont'd)

Depth (ft)	Lithology
to 192	Fresh grey BASALT
192 – 195	slightly weathered red/brown vesicular BASALT
195 – 225	Fresh grey BASALT
225 – 237	Faintly weathered red/brown vesicular BASALT
237 – 250	Fresh grey BASALT
250	End of Borehole

(2) (3) Completed Construction



During Drilling (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(L/s)~~ gpm	(6) ~~Other~~ Pen Rate mins/ft	After Drilling (2)(7) ~~Water Level (m)~~ T °C	~~Permeability (8)~~ (2) ~~Depth (m)~~ C	~~Method~~ pH	~~Value (cm/s)~~ eH	Comments
182			7.0	6.5	1000	7.51	+71	
187			5.0	6.5	1000	7.59	+114	
192			6.0	7	1000	7.79	+139	
197			3.4	7	1000	7.94	–	eH probe malfunctioning.
202			3.6	7.5	1000	7.77	–	
207			7.0	8	1050	7.38	–	208'-bit drops 6" through fracture.
212			9.2	7.5	1100	7.46	–	
217			9.4	8	1100	7.29	–	
222			9.0	8	1100	7.42	–	
227			5.0	7.5	1050	7.36	–	
232			7.6	8	1100	7.47	-	
237			5.0	7	1100	7.44	–	
242			5.0	7.5	1100	7.34	–	
			6.0					
249	57		–	7	1100	7.36	–	

Contractor: .... Logged by: ....

Date started: .... Checked by: ....

Date finished: .... Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW18

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/25/84

1:00	Started drilling 10"Ø open hole.
2:00	Set 10"Ø surface casing to 15.8'. Bedrock at 19'.
2:00 - 5:45	Drilling 10"Ø open hole to 75'. Hole caving. Hit water at 66.5' - 1 to 2 gpm. Cinder zone at 74 to 75'.
5:45	Pull rods.
6:00	Go for casing (8"Ø).

DATE: 09/26/84

7:00 - 8:45	Run 8"Ø casing to 77'.
8:45	Drilling from 77' - hole making 20 to 30 gpm water. 98' - weathered basalt vesicular? 104' - clayey layer?
5:30	162' (fresh basalt) end of shift.

DATE: 09/27/84

8:15	Start drilling. 166-1/2 to 168' clayey layer, greenish-grey. Eh probe seems to be malfunctioning. 191 to 193' some cinders? Vesicular basalt? Red/Brown. 206 to 206-1/2' bit falls - probably open fracture/void in basalt. 224-1/2' red/brown, water, weathered basalt - vesicular.
6:00	Pull rods from 250' - still in basalt.
6:00 - 7:00	Log hole for gamma, resistivity and S.P. Water level at 58'.

HISTORY OF HOLE

TW17

GEOLOGIST: D. Banton / M. Shaleen DATE: 09/28/84

Backfill hole to 242.7' with gravel. 80 lb bentonite pellets 242.7 to 238.1'. Gravel to 234.3'. Set 1x10' 4"Ø PVC screen 234.3 to 224.3'. Gravel pack to 219.3'. 60 lb Bentonite pellets 219.3 to 215.5'.

Run tremie pipe to 180'. Cement truck brings 400 gals with 73 bags cement. Add 100 lb bentonite powder and 25 lbs Flocele. Pump into hole.

DATE: 09/29/84

Sound grout to 73' below ground level. Pull out 77' 8" casing. Grouted surface with approximately 2 yds cement-sand grout. Water level at 17.95 m (58.89') below PVC casing.

WELL DEVELOPMENT - TW18

TW18 was developed on September 29th using air. The tremie pipe was set to 160 ft below ground level and air introduced. The well was developed for 35 mins. The water was clear at all times. The airlifted flow was estimated at 5 to 10 gpm.

Chemical parameters recorded during development are shown below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	Depth to Water Level (TOC) (m) TW16	Depth to Water Level (TOC) (m) TW17
0				18.895	18.875
5	6	1100	7.76		
15	6	1100	7.81	18.90	18.88
25	6.5	1100	7.81	18.90	18.875
35	7	1100	7.91		
After				18.90	18.88

A water sample was taken at the end of development for Monsanto.

No discernable change in water levels during development.

Fluoride Measurement = 0.34 mg/1

TW 19

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

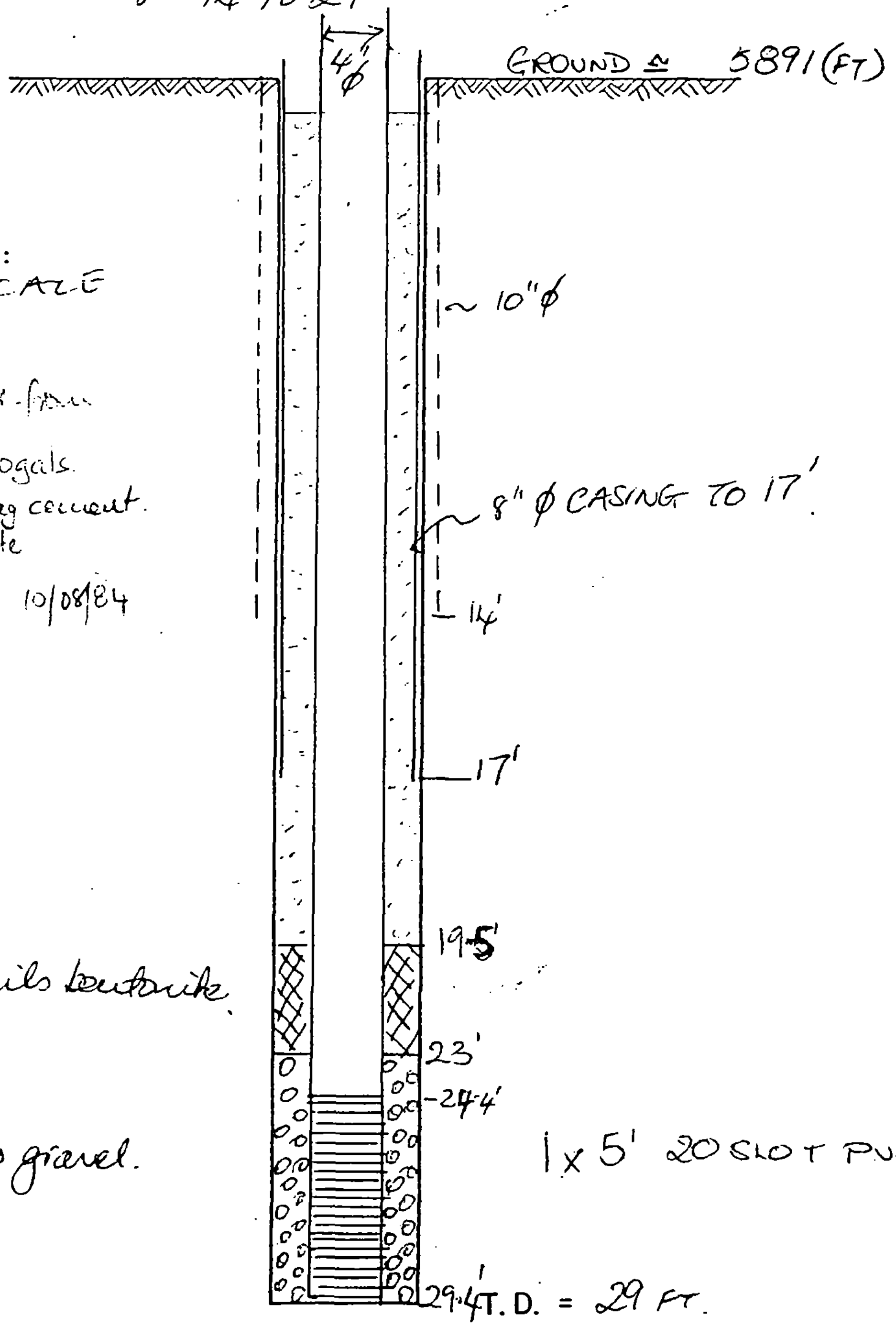
PIEZOMETER INSTALLATION DATA

Figure

TOP OF PVC = 5894.05'

BOREHOLE TW 19

HOLE DIAMETER 10" to 14'
8" 14 to 29'



REMARKS:
NOT TO SCALE

Grout pumped from
surface
approx ½ yard 100gals.
with 5½ gals H_2O / bag cement
1-2% bentonite
1-2% flocele
approx. 100gals 10/08/84

3 x 20 lb pails bentonite

6 x 20 lb pails gravel

1 x 5' 20 SLOT PVC

PROJECT NO. .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW 19
Sheet 1 of 1

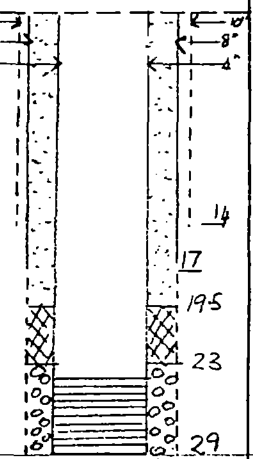
Job No.

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR / WATER

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation: 5891.0
Elevation type: surveyed ☑ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	(2) (4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(L/s)~~ gpm	(6) ~~Other~~ Pen. Rate mins/ft	After Drilling (2) (7) Water Level (m) ft	Permeability (2) Depth (m) Cu ft/min	Method pH	(8) Value (cm/s) eH	Comments
Ground Surface										
FILL - clayey GRAVEL 2.0	0" 8" 4"									
brown silty CLAY trace gravel 7.0										
10 brown gravelly SAND (basalt fragments) (weathered BASALT. 17.0	14 17									
20 Fresh grey BASALT	19.5 23				6.0 7.4					
	29	27	21	20-30	8.2	10	875	7.83	+96	Fracture at 27/28'
30 End of Borehole.										



Contractor: Andrew Well Drilling
Date started: 1st October 1984
Date finished: 1st October 1984

Logged by: DB/MLS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW19

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/01/84

10:25	Started drilling 10"Ø, drilled to 14' using 10"Ø bit.
11:00 - 11:20	Drillers pick up 8" casing.
11:20 - 11:30	Set 8" casing to 14'.
11:30 - 13:00	Drilling 8"Ø to 14 to 29'. Water found at 27' in fractured basalt. Pull rods from 29'.
1:30 - 2:30	Lunch.
2:30 - 3:15	Drillers weld on additional 2' casing - push casing to 17'.
3:15 - 4:05	Log hole for gamma and resistivity. Drillers p/u materials.
4:05 - 4:55	Set screen gravel pack and placed bentonite seal. 5'x20 slot PVC screen 29 to 24'. Gravel pack 29 to 23' with 6x20 lb pails gravel. Bentonite pellets 23 to 19.5' 3x20 lb bentonite pellets. Water level at approximately 21'. Flouride analysis = 1.55 mg/l.

DATE: 10/08/84

Grouted hole to within 3' of surface with cement, bentonite, Flocele grout when TW21 was grouted. Approximate volume 50 gals grout; 5-1/2 gals water/bag cement; 1 to 2% bentonite; 1 to 2% Flocele.

WELL DEVELOPMENT - TW19

This well was not developed by airlifting following completion, since wet ground conditions prevented access for the drilling rig. The well was developed by bailing on the day before sampling. 70 gals (5 well volumes) were removed from the well on November 13th, 1984. No measurements were made on the chemical quality of the bailed water. No water level recovery measurements were made following bailing.

TW 20

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

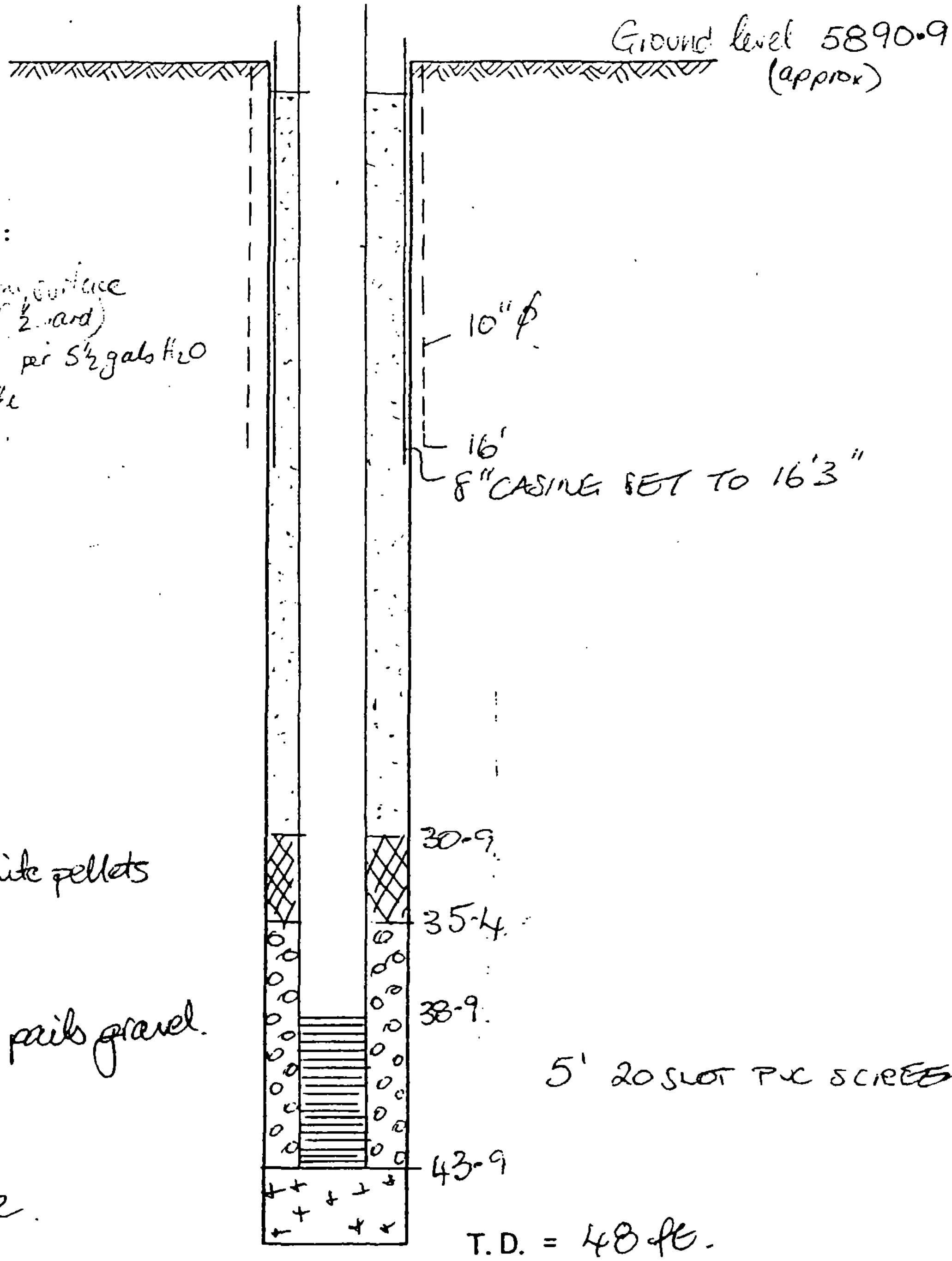
PIEZOMETER INSTALLATION DATA

Figure

TOP OF PVC
= 5894.26 (FT)

BOREHOLE TW 20.

HOLE DIAMETER 10" 0 to 16'
8" 16' to 48'



REMARKS:

Grout pumped from surface
approx 100 gals (½ yard)
with 1 bag cement per 5½ gals H_2O
1-2% bentonite
1-2% flocele.
10/08/84

70 lbs bentonite pellets

90 x gal pails gravel.

Cave.

PROJECT NO. .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW 20
Sheet 1 of 1

Job No.

Project: MONSANTO GROUNDWATER STUDY

Type of drilling: ROTARY

Rig: SCHRAMM T-64

Drilling fluid: AIR/WATER

Coordinates: E .... N ....

Angle from horizontal: 90°

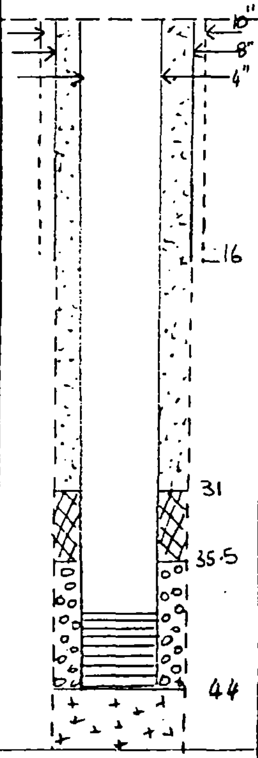
Bearing: – °Azimuth

Reference elevation: 5890.9

Elevation type: surveyed ☑ altimeter ☐ from map ☐

Purpose of hole: MONITORING WELL

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	During Drilling (2)(4) Water Level ~~(m)~~ ft	During Drilling (5) Water Flow ~~(L/s)~~ gpm	During Drilling (6) Other Pen. Rate mins/ft	After Drilling (2)(7) ~~Water Level (m)~~ T °C	After Drilling ~~Permeability~~ (2) Depth (m) C μS/cm	After Drilling ~~Method~~ pH	After Drilling (8) ~~Value (cm/s)~~ eH	Comments
Ground Surface	10" / 8" / 4"									
brown silty CLAY (0–8)										
10										
Fresh grey BASALT (fractured and faintly weathered below 27')					4.0					
	16				10.0					
20					6.8					
		27	21	20-30	6.0	10	800	7.68	–	
30	31	32			5.0	7.5	790	7.59	+203	
38	35.5	37			/	7	790	7.62	+169	
40 red/brown loose scoriacious CINDERS (38–48)	44				0.5					
48		47		100+	0.5	7	800	7.60	+203	
End of Borehole. 50										



Contractor: Andrew Well Drilling

Date started: 1st October 1984

Date finished: 2nd October 1984

Logged by: DB/MS

Checked by: ....

Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale: –

HISTORY OF HOLE

TW20

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/01/84

5:05 p.m.	Start drilling 10"Ø open hole. Bedrock at 8'.
5:45	Drilled to 16' at 10"Ø.
5:45 - 6:05	Set 16' of 8" casing in hole.
6:05 - 7:40	Drilling 8"Ø in bedrock 16 to 28'. Hole making 20 to 30 gpm at 27' in fractured basalt.

DATE: 10/02/84

7:15 - 8:35	Drilling 8"Ø. Hit cinder zone at 38' making 100 to 200 gpm caving. Hole drilled to 48' - caved back to 43'. Unable to drill further without washing out big cavity in cinder zone or setting casing.
9:10 - 9:45	Log hole gamma, resistivity and S.P.
9:50	Start well completion. Set 5'x20 slot screen 44 to 39' + 2x20' blank PVC + 1x10' blank PVC to surface. Gravel pack screen to 35.5' with 90x20 lb pails gravel. Bentonite pellets 35.5 to 31'. 70 lb pellets.

DATE: 10/08/84

Grout hole when TW21 grouted. Mixture of 5-1/2 gals water/bag cement; 1 to 2% Flocele; 1 to 2% bentonite. Approximately 75 gals grout pumped from the surface into annulus of hole to bring level to within 3' of surface. Water level at about 21'.

WELL DEVELOPMENT - TW20

TW20 was developed on October 18th, 1984, using compressed air. One inch pipe was set to a depth of 38 ft below ground level. The well was developed for 50 mins at a rate of approximately 50 gpm. The discharge water was clear at all times during development. Stevens water level recorders monitored water levels on TW19 and TW21 during development.

Chemical parameters recorded during development are shown below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	Eh (mV)
0				
3	5.5	775	7.78	+244
28	5.5	775	7.47	+285
50	5	750	7.49	+323*

*Sample taken for Monsanto

F = 2.15 mg/l

The water level in TW19 drew down 0.04' during the development of TW20. TW19 recovered soon after development ended. Water leven in TW21 did not respond to the development of TW20.

TW 21

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

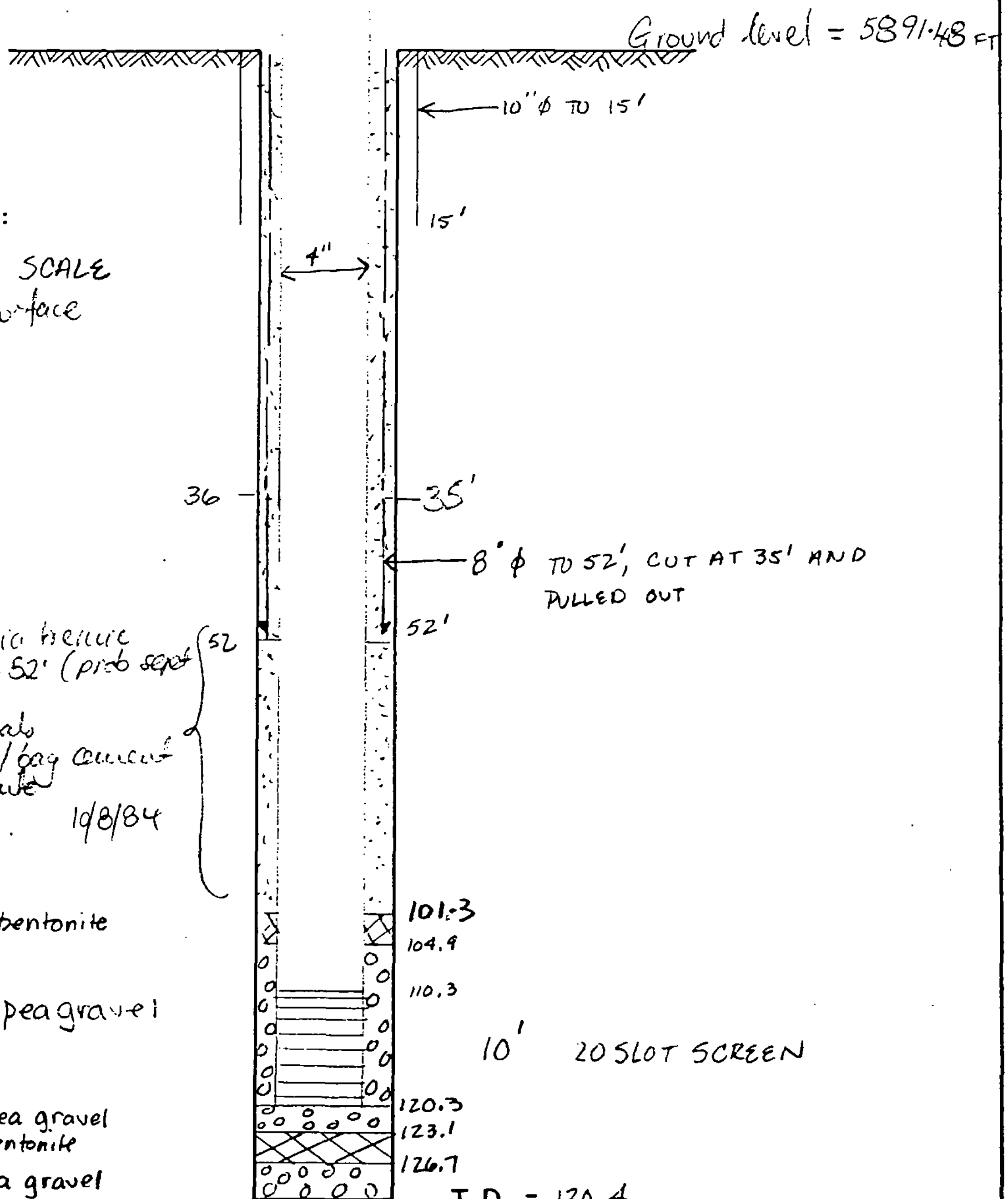
~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

TOP OF PVC
= 5894.41 FT

BOREHOLE TW21

HOLE DIAMETER 12" - 15'
10" = 43'
8" - 43'-130'



REMARKS:

NOT TO SCALE

Grouted to surface
on 9+11th Oct
2 x 1½ yards grout
1 yard = 48 gals H_2O
9 bags cement
2200 lbs sand

Grout pumped via tremie
pipe filled hole to 52' (prob seep
into cinder zone)
Grout mix @ 200 gals
5.5 gal H_2O / bag cement
12% bentonite
1.2% flocele. 10/8/84

2 x 50 lbs bentonite

7 x 50 lbs pea gravel

2 x 50 lbs pea gravel
2 x 50 lbs. bentonite
3 x 50 lbs. pea gravel

DATE
REVIEWED
DRAWN
PROJECT NO.

Golder Associates

HYDROGEOLOGIC LOG

DRILLHOLE No. TW21
Sheet 1 of 2

Job No.

Project: Monsanto Groundwater Study
Type of drilling: Rotary
Rig: Schramm T-64
Drilling fluid: Air/Water
Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing .... *Azimuth
Reference elevation: 5891.48
Elevation type: surveyed ☑ altimeter ☐ from map ☐
Purpose of hole: Monitoring Well

(1) (2)* Lithology	Depth (ft)	(2) (3) Completed Construction
Ground Surface	0	12", 10", 8", 4"
brown silty Sand and Gravel	0–8	
brown Sand and Gravel	8–13	
Fresh grey BASALT	13–41	35
red/brown loose scoriaceous CINDERS	41–52	52
Fresh grey BASALT	52–67	
...n ...yard ...l/brown ...iceous ...ERS	67–71	
Fresh grey BASALT	71–	

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80

During Drilling (2) Depth (ft)	(2)(4) Water Level (ft)	(5) Water Flow (gpm)	(6) Other Pen. Rate (mins/ft)	After Drilling (2)(7) Water Level T °C	Permeability (8) (2) Depth Cummins	Method pH	Value (cm/s) eH	Comments
			11					
			12					
30	21	30-50	11	9.0	875	7.55	195	
			12-13	6.5	800	7.66	155	Casing cut at 35'
			8	6.0	775	7.92	134	
		100+	2.0					
			4	7.5	800	7.53	170	
			7.6					
			6.1					
			1.5	8.5	800	7.45	138	
			4	9.0	825	7.46	160	
			1.8	8.0	800	7.58	170	
			3.	9.0	800	7.53	151	
			6.8					

Contractor: Andrew Well Drilling
Logged by: DB/MS
Date started: 2nd October 1984
Checked by: ....
Date finished: 6th October 1984
Date ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

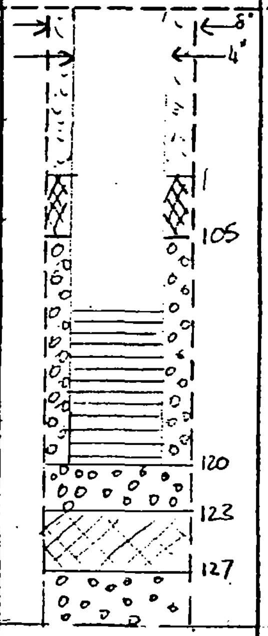
DRILLHOLE No. TW21
Sheet 2 of 2

Project: Monsanto Groundwater Study
Type of drilling: Rotary
Rig: Schramm T-64
Drilling fluid: Air / Water

Coordinates E ......
N ......
Angle from horizontal: 90°
Bearing ...... ° Azimuth

Reference elevation ......
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ......

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	(2) (4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) Other pen. rate mins/ft	After Drilling (2) (7) ~~Water Level (m)~~ T °C	~~Permeability (8) (2) Depth (m)~~ C umhos	~~Method~~ pH	~~Value (cm/s)~~ eH	Comments
Fresh grey BASALT (100)			92			8.0	800	7.50	126	
				8.8						
						8.0	800	7.40	138	
104				10.4		7.0	800	7.49	118	
red/brown faintly weathered vesicular BASALT 107				2.8						
						6.0	800	7.55	175	
110 Fresh grey BASALT				3.6		6.0	800	7.78	134	
116				5.6						
brown CLAY 118						8.0	800	7.86	—	
120				2.0						
						7.0	775	7.94	160	
Fresh grey BASALT (loose and fractured 118-122')				3.1		7.0	775	7.87	144	
130 130.5										
End of Borehole										

Contractor: ...... Logged by: ......
Date started: ...... Checked by: ......
Date finished: ...... Date ......

*** NOTE:** Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW21

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/02/84

1:40 p.m.	Began drilling 10"Ø. Bedrock at 12 to 13'. Basalt dry. 10" bit jamming at 17'. Pulled out 10" bit.
2:35 - 3:25	Reaming 12"Ø at 0 to 17'. Set 15' 10" casing in hole.
3:25 - 4:25	Repairing equipment.
4:25 - 7:40	Drilling 10"Ø at 17 to 33' - very slow. Water at 26 to 27', making 30 to 50 gpm at 30'.

DATE: 10/03/84

7:15	Started drilling - drilled to 43' at 10"Ø by 8:35. Cinders at 41' making lots of water - 100 to 200 gpm. Set 20' 8" casing in hole with drive shoe - rig broke down at 11:00 a.m.

DATE: 10/05/84

10:15 - 12:00 and 12:55 - 1.25	Welding on 8" pipe, setting up hammer - drove 8" pipe to approximately 52' (out of cinder zone).
1:25	Drilling 8"Ø open hole from 52'. Thin cindery zone at 67', otherwise basalt to 103'.
7:00	Stop drilling at 103'.

HISTORY OF HOLE

TW21

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/06/84

7:30 - 8:00	Pull drill stem, change tricone bit.
8:10	Start drilling - drilled to 130' by 9:30, clay 116 to 118', weathered basalt 104 to 107'.
9:30 - 10:00	Pull drill stem out of hole.
10:05 - 10:55	Log hole - natural gamma, S.P. and resistivity.
10:55 - 11:50	Backfill hole with gravel to 127' - 3x50 lb pails gravel; bentonite pellets 127 to 123' - 100 lb pellets; gravel to 120' - 2x50 lb pails gravel.
11:50	Hook up casing cutter to cut 8" casing in hole.
12:00	Run cutter to 35', start cutting.
12:25	Stop cutting - pull tool - 8" casing seen to move.
1:35 - 3:30	Set 10' 20 slot PVC screen at 120 to 110' + 6x20' blank PVC to surface. Gravel pack to 105' with 7x50 lb pails gravel, bentonite pellets at 105 to 101' - 2x50 lb bentonite pellets.

DATE: 10/08/84

9:15	Drillers on site after weekend.
9:15 - 9:30	Run 1"Ø pipe to 84' below surface.
9:30 - 10:10	Wait for Parsons cement truck with 73 bags cement - 400 gals water. Mix 50 lb bentonite powder + 12-1/2 lb Flocele.
10:10 - 11:15	Pump cement into TW20 and TW19 to top up. Then pump remainder (approximately 200 gals) into TW21. Pull out 1" tremie pipe and clean out cement mixer.
11:15 - 12:20	Pull out 35' of 8" casing (casing had been cut at 35' on October 6/84.
12:20 - 12:45	Cleaning up site. Hole grouted to surface with 2 loads of 1-1/2 yds of sand/cement grout on October 9th and 11th. Grout = 48 gals water/yd; 9 bags cement/yd; 2200 lbs sand/yd

WELL DEVELOPMENT - TW21

TW21 was developed on October 18th, 1984, using compressed air. One inch diameter pipe was set to a depth of 80 ft in the well. The well was developed for 40 mins at a rate of about 5 to 8 gpm. The discharge water was initially slightly cloudy; however, the water cleared up within 15 mins. Stevens water level recorders monitored the water level on TW20 as development was carried out.

Chemical parameters recorded during development are shown below:

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH	Eh (mV)
0				Eh Probe Damaged
5	5.5	1150	7.29	-
20	5.5	1100	7.42	-
40	6	1100	7.47	- *

*Water Sample Taken for Monsanto

F = 0.31 mg/l

No water level response was seen in TW20 during the dvelopment of TW21.

TW 22

i) Schematic Test Well Completion

ii) Field Borehole Log

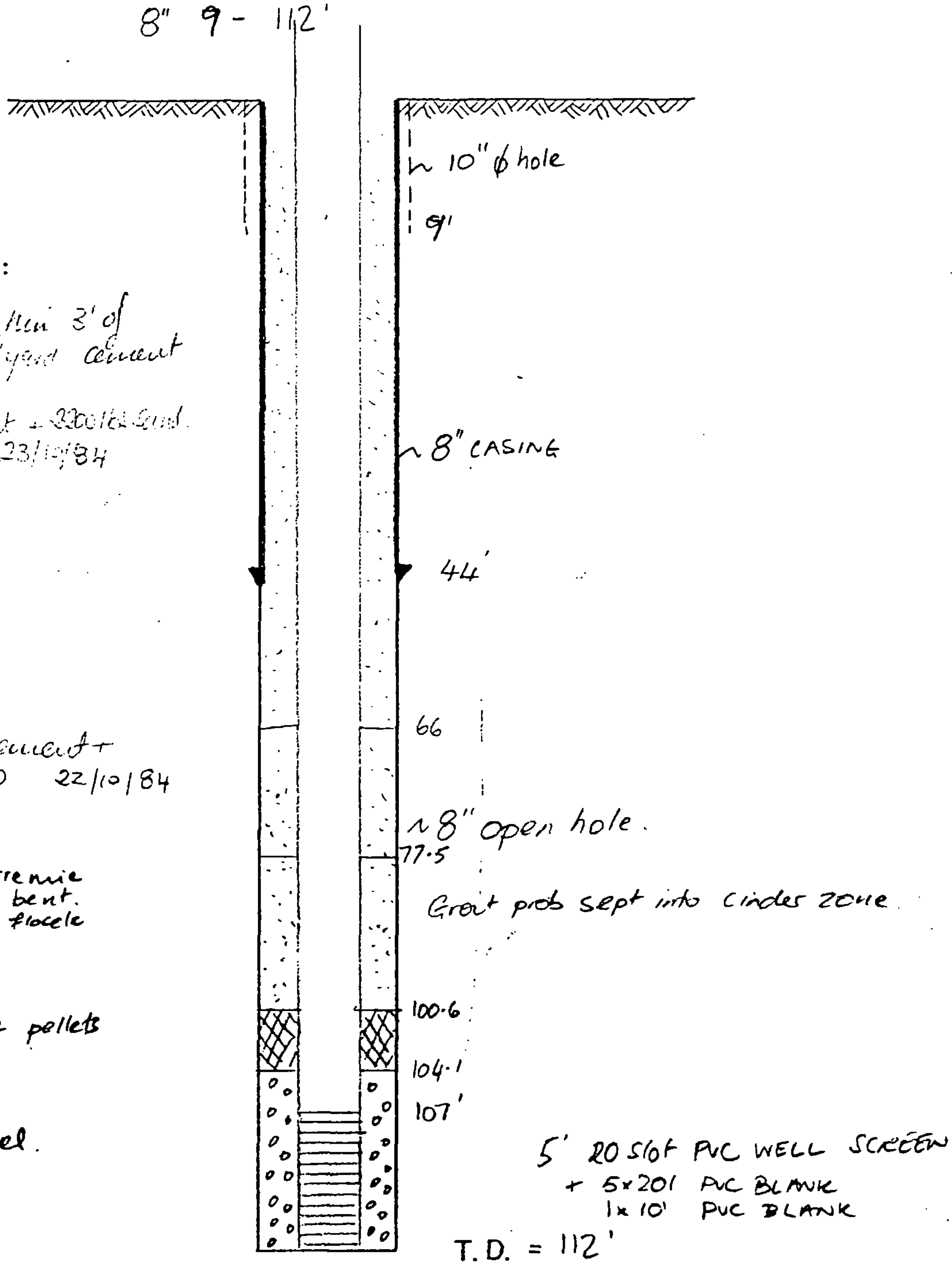
iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW22

HOLE DIAMETER 10" 0 - 9'
8" 9 - 112'



REMARKS:

Cemented to within 3' of
Surface with lyand cement
sand [illegible]
9 bags cement + 220 lbs sand.
23/10/84

Added 36 bags cement +
200 gals H_2O 22/10/84

Grout cet with tremie
200 gals H_2O 25 lbs bent.
6-7 lbs flocele
36 bags cement.

70 lbs bentonite pellets

11 x 2 gal. pails gravel.

DRAWN .... REVIEWED .... DATE .... PROJECT NO. ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW22
Sheet 1 of 2

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E
N
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) ~~Other~~ Pen. Rate mins/ft	After Drilling (2)(7) ~~Water Level (m)~~ T °c	~~Permeability (8)~~ ~~(2) Depth (m)~~ C uS/cm	~~Method~~ pH	~~Value (cm/s)~~ eH	Comments
Ground Surface										
0–4: Grey GRAVEL and COBBLES (FILL)	10" to 4; 8" to 7; 4"									
4–20: Brown/black silty SAND (TAILINGS)										
20–27: Brown silty CLAY										
27–38: Brown silty SAND with weathered BASALT										
38–44: Fresh/faintly weathered red/grey vesicular BASALT	44									
44–75: Fresh grey BASALT					6					
					6					
					6					
					3					
					6					
75–89: Red/brown loose scoriacious CINDERS		82	67.3			13.5	1800	7.31	+140	F=18.7mg/l
89–90: Fresh grey BASALT					2.5					

Depth scale marks: 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling	Logged by: DB/MS	* NOTE: Bracketed numbers refer to notes preceding the logs.
Date started: 8th October 1984	Checked by:	**Golder Associates**
Date finished: 16th October 1984	Date:	Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW22
Sheet 2 of 2

Project ....

Type of drilling .... Coordinates: E .... N ....

Rig ....

Drilling fluid .... Angle from horizontal ....

Bearing .... °Azimuth

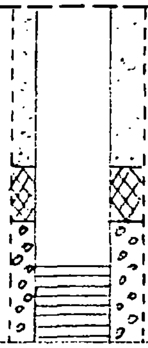
Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth (~~m~~)	During Drilling (2)(4) Water Level (~~m~~)	During Drilling (5) Water Flow (~~L/s~~)	During Drilling (6) ~~Other~~ Pen Rate	After Drilling (2)(7) Water Level (~~m~~)	Permeability (8) (2) Depth (~~m~~)	Permeability (8) Method	Permeability (8) Value (~~cm/s~~)	Comments
90 cont'd		ft	ft	gpm	mins/ft	Tc	Cu/lu	pH	eH	
					2.5					
Fresh grey BASALT					10					
100	100.5				10					
	104				8					
107										
Faintly to slightly weathered red/brown BASALT. 110 112	112	112	67.1	50-70	3					
End of Borehole										



Contractor: ....
Date started: ....
Date finished: ....
Logged by: ....
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW22

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/08/84

p.m. 6:00 - 7:15	Move and set up over hole.
7:25 p.m.	Start drilling 10"Ø through dense grey slag. Hit brown/black silty sand at 4' - wet at 7' - need to drive casing to keep open.

DATE: 10/03/84

a.m. 8:00 - 11:30	Drill and drive 8"Ø casing to 44' - weathered basalt? at 35'(?), dense grey basalt at 44'. Dry.
11:30 - 12:00	Remove casing hammer, pull out drill string and change to 8" bit with centralizer.
1:00 - 4:30	Drilling 8"Ø open hole 44 to 89'. Hit water at 75' in loose cinder zone - loss of cuttings and water - caving back on bit. Decide to stop hole at this depth and probably complete in this zone.
	Logger not available therefore move over and start no new hole. Water level at 66.6'. Water sample for flouride gives 18.7 mg/l. Conductivity 1800μmhos/cm.

HISTORY OF HOLE

TW22

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/16/84

7:05	Move back onto hole (depth = 89'), water level at 67.26' below ground.
8:35	Started drilling 8"Ø from 89' - some foam added to bring cuttings to surface.
11:20	Drilled to 112' - hit weathered basalt zone at 107' - picked up some water.
11:25 - 12:15	Log hole for gamma and resistivity. Water level at 20.57 m (67.5') below casing (s/u = 0.1 m), therefore water level = 67.15' below ground level.
12:35	Installation - set 1x5' 20 slot PVC screen; 5x20' blank PVC and 1x10' blank PVC. Gravel pack screen with 112 gal pails gravel to 104.1'; 70 lb bentonite pellets at 104.1 to 106'. Run 1" tremie pipe to 84'. Pump 200 gals grout with 5-1/2 gals water/bag cement, 25 lbs bentonite and 6 to 7 lb Flo-cele.

DATE: 10/17/84

Sounded grout to 23.68 m (77.69') below ground.

DWT inside well = 21.35 m (70.04')

DWT outside pipe = 21.40 m (70.20') - probably reflects head in overlying zone, therefore upward flow potential.

DATE: 10/22/84

Added 36 bags cement and 200 gals water to annulus of hole - cement added from surface since only 7' of water in bottom of hole. Most of grout appeared to seep into fractured rock. Sounded to 66' afterwards.

DATE: 10/23/84

Add 1 yd cement/sand mixture to well - filled annulus to within 3' of ground level. Mixture = 9 bags cement to 48 gals water + 2200 lbs sand.

WELL DEVELOPMENT - TW22

TW22 was developed with compressed air on November 22nd, 1984. One inch diameter tremie pipe was set to 100 ft and the well developed for approximately 1 hr at a rate of 20 to 25 gpm. The discharge water was initially a dirty red-brown; however, it cleared up after 5 to 10 mins of developing. Stevens' water level recorders monitored water levels on TW23 and TW24 during the airlifting.

Chemical parameters for TW23 are shown below:

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH
8	9	1775	7.69
25	9	1825	7.52
40	9	1800	7.52
55	8.5	1800	7.56

F = 6.4 mg/l

The water level in TW24 drew down 0.24 ft during the development of TW22. The water level in TW23 did not change during the same period.

The water level in TW22 had nearly recovered its original level approximately one day after development ended.

TW 23

i) Schematic Test Well Completion

ii) Field Borehole Log

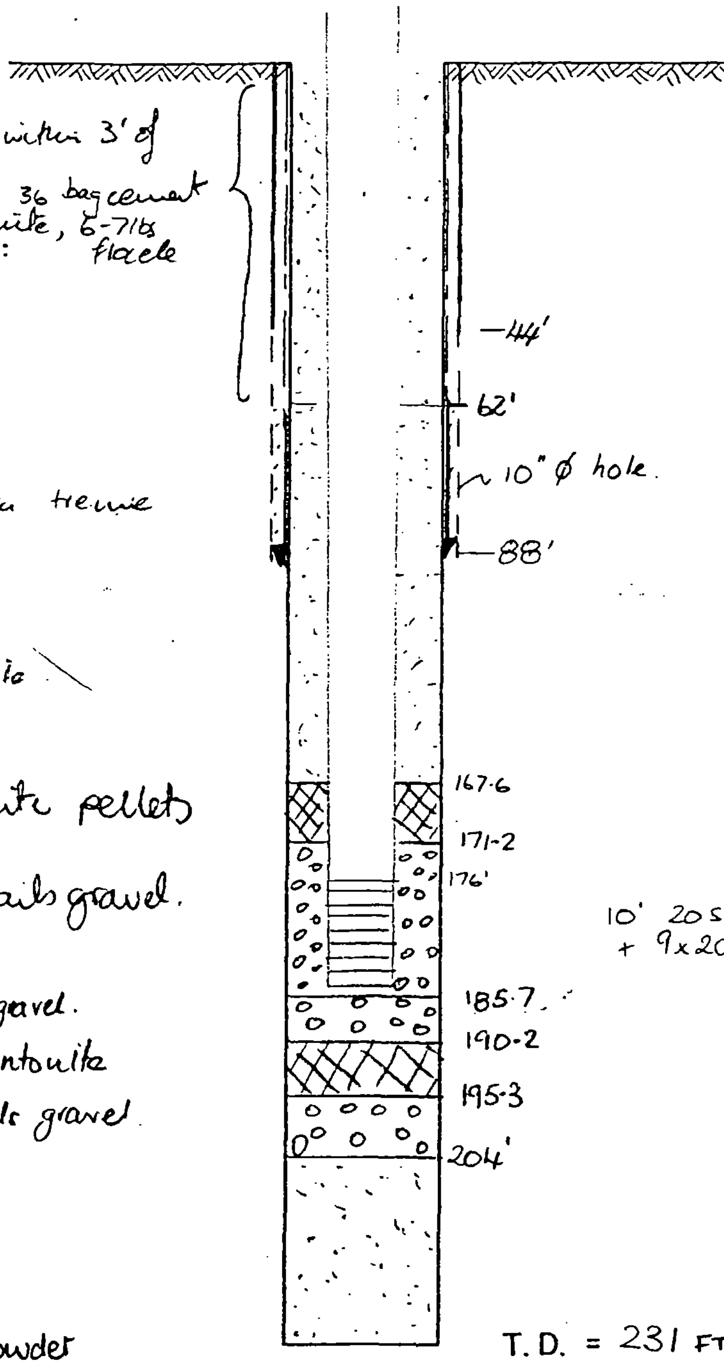
iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW23

HOLE DIAMETER 10" 0 to 88'
8" 88 - 231 FT.



REMARKS:

topped up to within 3' of surface
200 gals H_2O 36 bag cement
25 lb bentonite, 6-7 lbs flocele

10" CASING DRIVEN TO 44'
HOLE DRILLED 10" ø to 88'
SET 88' 8" CASING WITH DRIVE SHOE
CUT + PULLED 62' 8" CASING AFTER GROUTING

Pumped grout via tremie pipe
55 bags cement
300 gals H_2O
15 lbs flocele
40 lbs bentonite

90 lbs bentonite pellets

8x5 gallon pails gravel.

10' 20 SLOT PVC SCREEN + 9x20' blank PVC pipe.

4x 5 gallon pails gravel.

2x 50 lb pails bentonite

6x 5 gallon pails gravel

Cement slurry
100 gals H_2O
7 lb flocele
20 lb $CaCl_2$
30 lb bentonite powder

T.D. = 231 FT.

DATE .... REVIEWED .... DRAWN .... PROJECT NO. ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW23
Sheet 1 of 3

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER
Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth
Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(L/s)~~ gpm	(6) ~~Other~~ Pen. Rate min/ft	After Drilling (2)(7) Water Level ~~(m)~~ T °C	Permeability (8) (2) Depth (m) C us/cm	Method pH	Value (cm/s) eH	Comments
Ground Surface										
Grey GRAVEL and COBBLES (FILL) 4	10" / 8" / 4"									
Brown/black silty SAND (TAILINGS) 20										
Brown silty CLAY 27										
Brown silty SAND with weathered BASALT 38										
Fresh/faintly weathered red/grey vesicular BASALT 44	44									
Fresh grey BASALT 75	62				10					
					11.6					
					9					
					12					
					9					
Red/brown loose scoriacious CINDERS 88	88	82	67	50	1	12	1525	7.41	+91	
					4					
Fresh grey BASALT					3.7					

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling
Date started: 9th October 1984
Date finished: 15th October 1984
Logged by: DB/KJS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW23
Sheet 2 of 3

Project ....
Type of drilling ....
Rig ....
Drilling fluid ....
Coordinates: E ....
N ....
Angle from horizontal ....
Bearing .... °Azimuth
Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ....

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2)(4) Water Level ~~(m)~~	(5) Water Flow ~~(L/s)~~	(6) ~~Other~~ Pen. Rate	After Drilling (2)(7) Water Level ~~(m)~~	Permeability (8) (2) Depth (m)	Method	Value (cm/s)	Comments
90 Contd		ft	ft	gpm	mins/ft	T °C	C µS/cm	pH	eH	
Fresh grey BASALT	8"				3.7					
	4"	92			8.4	12	1620	7.27	—	Eh probe malfunctioning
		97			6.6	12	1600	7.64	—	
100		102			4	11.5	1575	7.66	—	
105 Faintly to slightly weathered, red/brown BASALT, trace clay 109		107		70-80	4.	11	1775	7.57	—	
110 Fresh grey BASALT		112			3	11	1725	7.55	—	
		117			2.6	10	1725	—	—	
120		122			2.6	10	1725	7.66	—	
		127			6.3	10	1700	7.63	—	F = 8.0 @ 159'
130					6.3					
		137			7	10	1625	7.28	+33	
140		142			6	10.5	1625	7.65	-31	
		147			7	10.5	1600	7.65	+72	
150		152			8	10.5	1590	7.59	+19	
		157			11	10.5	1550	7.56	+86	
160		162			4	10.5	1525	7.35	+11	
165 Slightly weathered, red/brown BASALT - loose 168	167.5	167			1.5	10.5	1550	7.37	—	
170 Red/brown CLAY 170	171	172			2	10	1500	7.39	—	
Slightly weathered red/brown BASALT (loose) 178				100-200	2					
180 Fresh to faintly ~~weathered~~ grey BASALT - fractured		177				9.5	1350	7.21	—	

Contractor ....
Date started ....
Date finished ....
Logged by ....
Checked by ....
Date ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW23
Sheet 3 of 3

Project ....
Type of drilling ....
Rig ....
Drilling fluid ....
Coordinates: E ....
N ....
Angle from horizontal ....
Bearing .... ° Azimuth
Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ....

Job No. ....

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~	During Drilling: (2) (4) Water Level ~~(m)~~	During Drilling: (5) Water Flow ~~(l/s)~~	During Drilling: (6) ~~Other~~ Pen. Rate	After Drilling: (2) (7) Water Level ~~(m)~~	After Drilling: Permeability (8) ~~(2) Depth (m)~~	After Drilling: Permeability (8) ~~Method~~	After Drilling: Permeability (8) ~~Value (cm/s)~~	Comments
180' Cont'd		ft	ft	gpm	mins/ft	T °C	C uS/cm	pH	eH	
Fresh to faintly weathered grey BASALT (fractured)	8" / 4"	182			2	9	1300	7.15	—	
	186	187			3	9	1300	7.07	—	
188										
190	190	192			12	11	1475	7.01	—	
	195				8					
Fresh grey BASALT		197			7	9	1300	6.96	—	
200										Fracture at 203'
	204	202			6	8	1200	6.78	—	
		207			9	8	1200	6.74	—	
210		212			8	8	1200	6.68	—	
		217			12	8	1175	6.61	—	Fracture at 216'
220		222			14	8	1175	6.67	—	
		227	67.5	100 - 200	10	8	1150	6.71	—	F = 1.5 @ 229'
230 231	231									
End of borehole										

Contractor: ....
Date started: ....
Date finished: ....
Logged by: ....
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW23

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/09/84

p.m. 5:20 - 5:25	Move and set up over hole.
5:25 - 5:35	Hook up hammer to drive 10"Ø casing.
5:35 - 5:50	Drill 10"Ø open hole 0 to 8' to penetrate dense slag.
5:50 - 6:10	Weld on 'drive shoe' to 10" casing (drive shoe is 10" casing pushed over 10"). Set 10" casing in hole. 1st length = 5'4", 2nd length 20'0" = total length 25'4".
6:50	Drove casing to 23'.

DATE: 10/10/84

3:15 p.m.	Add 20' 10" casing. Drove to 44'. Total 45'4".
4:45	Take off hammer - start drilling open hole. 10"Ø.
4:45 - 8:00	Drilling 10"Ø open hole at 44 to 68'. No water - fresh grey basalt.

DATE: 10/11/84

a.m. 7:05 - 10:00	Drilling 10"Ø at 68 to 88'. Hit cinders zone at 75' making water - about 50 gpm.
10:00 - 10:50	Drillers pick up casing (8").
10:50 - 12:20	Weld and set 8" casing with drive shoe to 75'.
1:20 - 3:00	Weld and set 8" casing with drive shoe to 89'.
3:00 - 6:45	Drilling 8"Ø at 89 to 131'. 89 to 105' fresh grey basalt, 105 to 108' weathered basalt. Pick up water through weathered zone. Increase in specific conductance of water?
6:45	Drawdown chain snaps in two places. Links need to be replaced.

HISTORY OF HOLE

TW23

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/12/84

8:00 - 1:30	Drillers fixing drawdown chain with new links. Will have to replace chain, but drilling can carry on though not at full down pressure.
1:30 - 7:20	Drilling 8"Ø open hole 131 to 191'. Fresh grey basalt at 131 to 164/65'. Slow drilling. Fast drilling at 164/65 to 186'. Clay at 168 to 170', weathered basalt at 165 to 186' and 170 to 178', fractured basalt at 178 to 188'. Increase in water flow through this zone - 100 to 200 gpm. Decrease in ground water conductance and pH.

DATE: 10/13/84

7:15 - 12:05	Drilling 8"Ø open hole 191 to 225'. Fresh grey basalt. Very slow drilling progress. Possibly fractured at 203' and may have picked up some water - greenish.
12:05 - 1:15	Lunch.
1:15 - 2:10	Drilling 225 to 231' - slow progress.
2:10 - 2:45	Pull out drill string.
2:45 - 4:15	Logging hole using natural gamma, resistivity and S.P.
4:15 - 4:30	Stand by while call for cement to backfill hole. Run tremie pipe to 230' to pump grout down. Depth to water in hole 20.88 m (68.50'); s/u 0.30 m (1') = 20.58 m (67.5') below ground. Cement truck arrives - mix in 1/3 bag Flocele (7 to 8 lbs); 20 lb $CaCl_2$; 20 to 30 lb bentonite. Pumped down tremie pipe to base of well.

DATE: 10/14/84

Sounded depth to grout as 204' below ground.

HISTORY OF HOLE

TW23

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/15/84

10:00	Run casing cutter to 62' - cut 8" casing.
10:00 - 1:00 and 1:00 - 4:00	Backfill hole with gravel 204 to 195.3' - 6x5 gal pails gravel. Place bentonite pellet seal 195.3 to 190.2 (100 lb pellets). Pea gravel 190.2 to 185.7' - 4x5 gal pails gravel. Set 10' 20 slot PVC well screen at 185.7 to 175.7' + 9x20' blank PVC pipe to surface - joints teflon wrapped. Gravel packed screen to 171.2' with 8x5 gal pails gravel. Bentonite seal 171.2 to 167.6' - 90 lb bentonite pellets.
4:00	Run 1"Ø tremie pipe to 145'. Cement mixed by Parsons - 55 bags cement, 300 gals water, added 15 lbs Flocele and 40 lbs bentonite. Mixed for 10 mins in mixer - pumped into hole.
5:25	Pull out tremie pipe, clean up.
5:50 - 7:05	Pull out 62' 8" steel casing.

DATE: 10/16/84

Sounded grout to 19.025 m (62.4') below ground (above water level in hole). Topped off to within 3' of surface with 200 gals water, 36 bags cement, 25 lbs bentonite and 7 lbs Flocele.

WELL DEVELOPMENT - TW23

TW23 was developed with compressed air on November 2nd, 1984. One inch diameter tremie pipe was set to 164 ft below ground. The well was developed at a rate of 15 to 20 gpm for 1 hour. The discharge water had a slight reddish tinge during development. Stevens' water level recorders monitored water levels on TW22 and TW24 during the airlifting.

Chemical parameters recorded during development are shown below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH
5	7.5	1210	10.65(?)
20	7	1250	7.95
40	6	1200	7.68
55	6	1150	7.53

F = 1.3 mg/l

Water levels in TW22 and TW24 were still recovering following development of these wells when TW23 was developed. However, no impact on the recovery in either well was seen.

TW 24

i) Schematic Test Well Completion

ii) Field Borehole Log

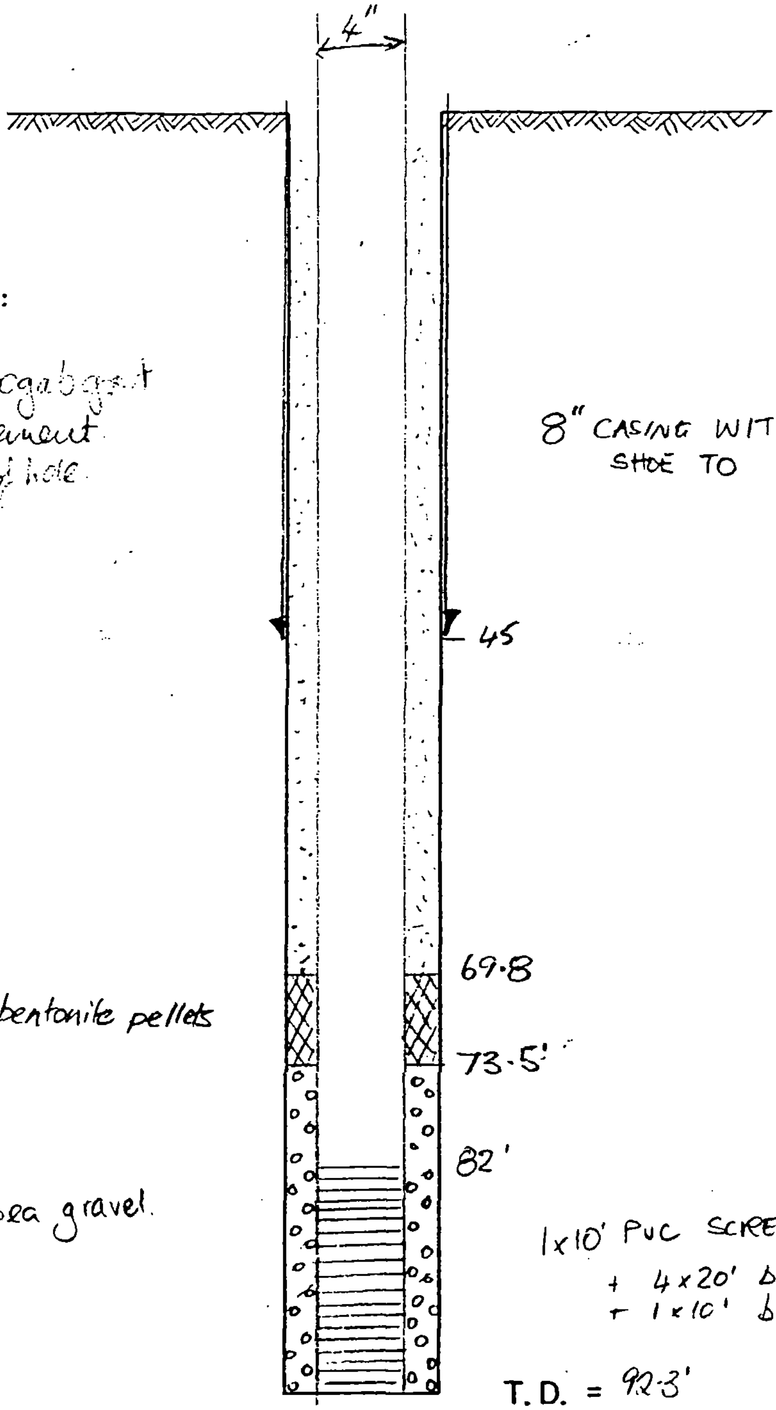
iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW24.

HOLE DIAMETER 8" 0' to 92'.



REMARKS:

22/10/84 Added 200gals grout = 36 bags cement to annulus of hole.

8" CASING WITH DRIVE SHOE TO 45 ft

50 lbs bentonite pellets

91 gals pea gravel.

1x10' PVC SCREEN. 20 SLOT.
+ 4x20' blank pvc
+ 1x10' blank PVC.

T.D. = 92·3'

PROJECT NO. .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW24
Sheet 1 of 1

Job No.

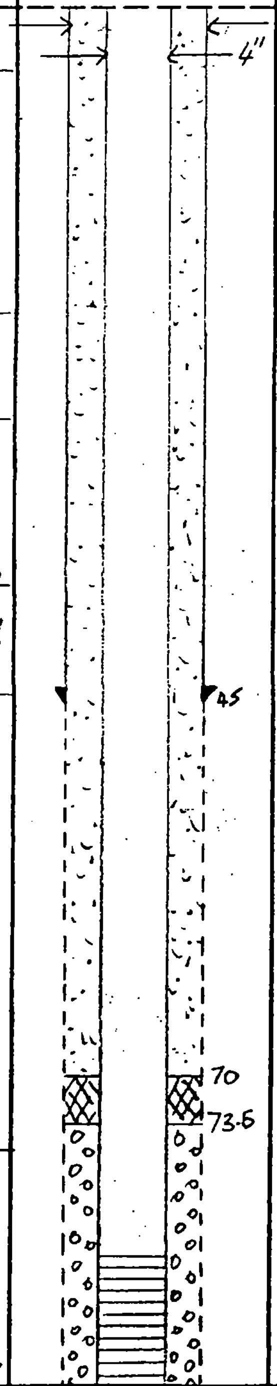
Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing .... *Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) Other Pen. Rate min/ft	After Drilling: (2)(7) Water Level (m)	Permeability (8): (2) Depth (m)	Method	Value (cm/s)	Comments
Ground Surface		ft	ft	gpm	min/ft					
Grey GRAVEL and COBBLES (FILL) 4	8" / 4"									No chemical parameters recorded.
Brown/black silty SAND (TAILINGS) 20										
Brown silty CLAY 27										
Brown silty SAND and weathered BASALT. 38										
Fresh/faintly weathered red/grey vesicular BASALT 45	45									
Fresh grey BASALT					7					
					7					
					6					
					9					
					7					
	70									
75	73.6	75	67	50	5					
Red/brown loose scoriacious CINDERS					1.6					
					1.6					
					1.6					
End of Borehole 93'										

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90



Contractor: Andrew Well Drilling
Date started: 16th Oct 1984
Date finished: 18th Oct 1984
Logged by: DB/MS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW24

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/16/84

p.m. 5:45 - 6:05	Move and set up on TW24, hook up casing hammer.
6:05 - 6:40	Weld on 8" drive shoe to 8" pipe.
6:40	Start drilling and driving 8" casing. Driven to 18' by 7:00 p.m. 0 to 4' slag, 4 to 18' tailings.

DATE: 10/17/84

7:10	Add 8" casing - 14' long. Approximate total 34'.
8:35	Finished welding - driven to 32' by 9:35 a.m.
9:35 - 11:30	Drillers look for hose clamp and wind break for protection from snowstorm.
1:00 to 1:15	Welding on 14'4" 8" casing - total = 48'4". Driven to 45'.
1:50	Drilling open hole 45'.
1:50 - 6:05	Open hole drilling 8"Ø - 45 to 92'. No water 'til 75' - entered cinder zone - 50 gpm. Response to drilling seen in TW22, 5 cm drawdown.
6:05 - 6:30	Pull out drill string. Prepare to set screen. Monsanto has logger, therefore no log.
6:30 - 7:00	Set 1x10' PVC screen 20 slot + 4x20' blank PVC + 1x10' blank PVC.

HISTORY OF HOLE

TW24

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/18/84

7:00 - 8:20 Gravel pack screen from 92 to 73.5' with 91 gals pea gravel. 50 lb bentonite pellets - 73.5 to 69.8'.

DATE: 10/22/84

Grouted to within 3' surface with 36 bags cement and 200 gals water. Water level outside well before grouting = 20.3 m (66.6') below well casing. Water level inside well = 70' from same datum. Therefore downward head.

WELL DEVELOPMENT - TW24

TW24 was developed on November 2nd, 1984. One inch diameter tremie pipe was set to 80 ft and the well developed for 55 mins at a rate of 3 to 5 gpm. Stevens' water level recorders monitored the water level response in TW22 and TW23.

Chemical parameters recorded during development are shown below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH
10	7	1300	10.76
20	6	1400	9.19
35	7	1425	8.85
45	6	1425	8.67
55	6	1400	8.64

F = 9.3 mg/l

No response was observed in TW23 while TW24 was developed. TW22 was recovering as TW24 was developed; however, TW22 drew down 0.02 ft as TW24 was being developed.

TW 25

i) Schematic Test Well Completion

ii) Field Borehole Log

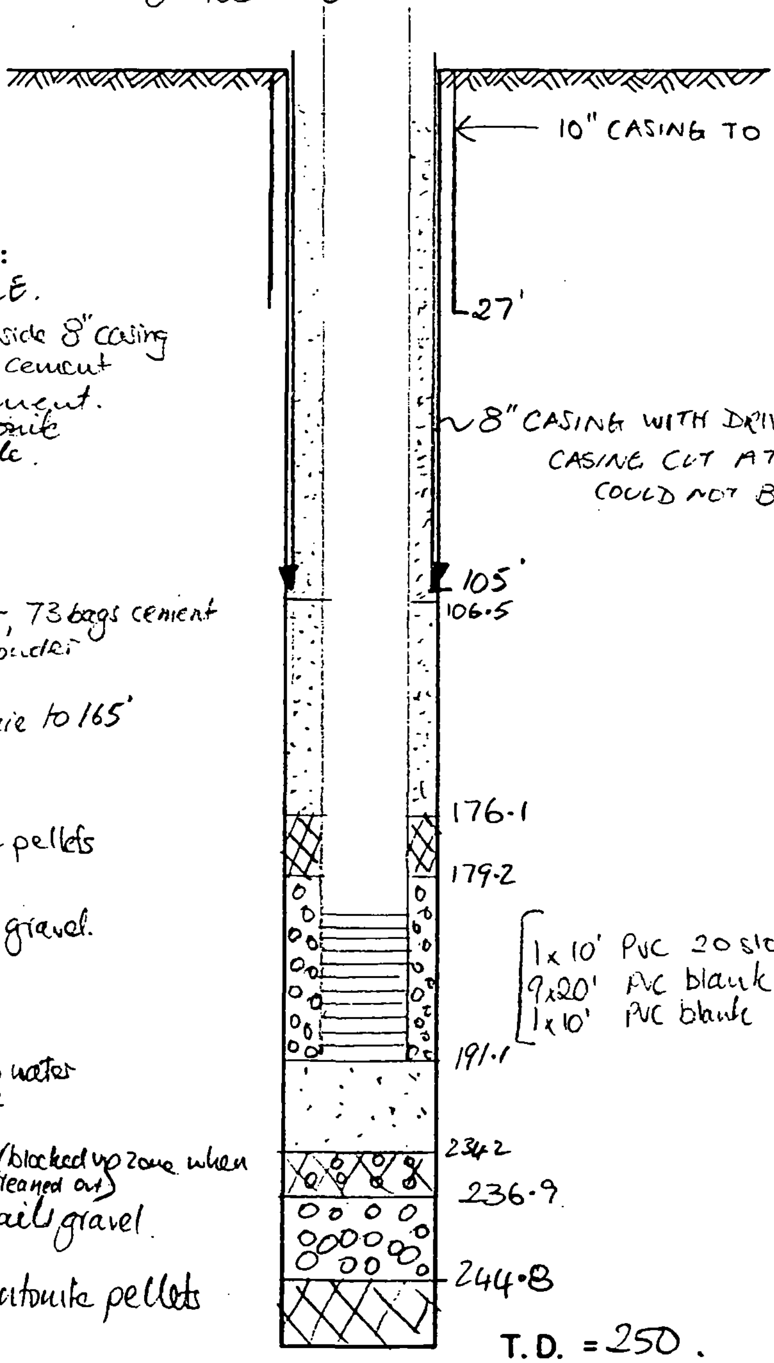
iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW25.

HOLE DIAMETER 10" to 105'
8" 105-250'.



10" CASING TO 27' (SHOE IS EXTRA PIECE OF 10" PIPE WELDED OVER)

8" CASING WITH DRIVE SHOE TO 105'
CASING CUT AT 80' and 50' BUT COULD NOT BE PULLED OUT

REMARKS:

NOT TO SCALE.

Grouted to surface inside 8" casing with approx 200 gals cement with 36 bags cement.
25 lbs bentonite
7 lbs flocele.
(11/3/84)

Grout - 400 gals water, 73 bags cement
50 lbs bent powder
12½ lbs flocele
Pumped via tremie to 165'

150 lbs bentonite pellets

13 x 2 gal pails gravel.

1 x 10' PVC 20 slot screen
9 x 20' PVC blank 4" ϕ
1 x 10' PVC blank

11 bags cement - 60 gals water
trace bentonite + flocele

Mixture of bentonite + gravel (blocked up zone when hole cleaned out)

14½ x 2 gal pails gravel

150 lbs bentonite pellets

T.D. = 250.

PROJECT DRAWN REVIEWED DATE

Golder Associates

HYDROGEOLOGIC LOG

DRILLHOLE No. TW25
Sheet 1 of 3

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER
Job No.

Coordinates: E ...
N ...
Angle from horizontal ...
Bearing ... °Azimuth

Reference elevation ...
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth (m)	During Drilling: (2)(4) Water Level (m)	During Drilling: (5) Water Flow (L/s)	During Drilling: (6) Other Pen. Rate	After Drilling: (2)(7) Water Level (m)	Permeability (8): (2) Depth (m)	Permeability (8): Method	Permeability (8): Value (cm/s)	Comments
Ground Surface:		ft	ft	gpm	mins/ft	T°C	Cus/cm	pH	eH (mV)	
10, 20 — Grey/silty GRAVEL and COBBLES (FILL) — 26	10", 8", 4"; 27									
26 — Fresh grey BASALT — 30 — 33					3					
33 — Brown/black silty SAND					4					
40 — Fresh grey BASALT. — 50					6, 4					
50 — Brown/black silty SAND — 52					2					
52 — Red/brown sandy SILT to silty SAND — 59					4					
59 — 60, 70, 80, 90 — Fresh grey BASALT.					4, 6, 8, 8, 4, 7					

Contractor: Andrew Well Drilling
Date started: 18th October 1984
Date finished: 31st October 1984
Logged by: DB/MS
Checked by: ...
Date: ...

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW25
Sheet 2 of 3

Job No.

Project ....

Type of drilling ....

Rig ....

Drilling fluid ....

Coordinates: E ....
N ....

Angle from horizontal ....

Bearing .... °Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth (~~m~~)	During Drilling: (2) (4) Water Level (~~m~~)	During Drilling: (5) Water Flow (~~l/s~~)	During Drilling: (6) Other Pen. Rate	After Drilling: (2) (7) Water Level (~~m~~)	~~Permeability~~ (8): (2) Depth (m)	~~Permeability~~ (8): Method	~~Permeability~~ (8): Value (cm/s)	Comments
cont'd		ft	ft	gpm	mins/ft	T °C	C uS/cm	pH	eH (mV)	
Fresh grey BASALT 93	10" 8"				3					
Faintly weathered BASALT, fractured 97	4"				2					
100		99		5		18	1400	7.93		loose circulation at 99'
Fresh grey BASALT	105	105	87.3		4					Hole caving @ 105'
					7.5					
110					4					
116					6					
Fresh grey BASALT 120 and brown fine SAND 123					3	9	1200	7.23		
Fresh grey BASALT					5					
130 132					3					
Red/brown silty CLAY 134						16	1450	7.34		
Red/brown fine SAND 137					1.5					
Faintly weathered 140 red/brown vesicular BASALT with some CINDERS (loose) 146					2.5	12	1250	7.36		
					3	10.5	1250	7.58		
Fresh grey 150 BASALT					5	10	1300	7.56		
156					3	10.5	1300	7.57		
Faintly weathered red/brown BASALT 159					7	10	1350	7.55		
160 Fresh grey BASALT					5	10	1350	7.58		
						10	1350	7.59		
170						8	1310	7.44		
	176				7	9.5	1300	7.51		
180 180	179				4					

Contractor ....
Date started ....
Date finished ....

Logged by ....
Checked by ....
Date ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW25
Sheet 3 of 3

Job No.

Project ....

Type of drilling ....

Rig ....

Drilling fluid ....

Coordinates: E ....

N ....

Angle from horizontal ....

Bearing .... °Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

(1) (2)* ~~Lithology~~	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ ft	(6) Other Pen. Rate mins/ft	After Drilling: (2)(7) Water Level ~~(m)~~ T°C	Permeability (8): (2) Depth (m) Cus/cm	Method pH	Value (cm/s) eH	Comments
Contd										
Faintly weathered red/brown to grey BASALT 185	8" 4"				4	9	1325	7.52		
Fresh grey 190 BASALT 193	191				6	9.5	1325	7.42		
					6	8.5	1275	7.55		
Faintly weathered red/brown to grey fractured 200 BASALT 201					2	9	1275	7.60		
					3	8.5	1275	7.72		
					4	9.5	1250	7.87		
210 Fresh grey BASALT.					6	9	1250	7.88		
					4	9.5	1250	7.97		
220					6	9	1250	~~7.89~~		
					6	9	1250	7.97		
230 233					3	8.5	1250	7.77		
Faintly weathered red/brown-grey fractured BASALT 237	234 237				3	9	1250	7.75		
240 Fresh grey BASALT					5	9	1275	7.77		
	245				4	9	1290	—		
250	250									
End of Borehole										

Contractor .... Logged by: ....

Date started: .... Checked by: ....

Date finished .... Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW25

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/18/84

p.m. 3:10	Started drilling 10"Ø open hole - drilled 5' through slag. Hole caving - therefore go to pick up casing.
4:10	Weld on 10" drive shoe to 10" casing.
5:00 - 6:30	Drilled and drove 10"Ø casing to 27' using casing hammer. Bedrock at 26/27'. Total casing set = 27' (10"Ø).

DATE: 10/19/84

7:15 - 7:55	Take off casing hammer - cut 10" casing at ground level.
7:55 - 8:55	Drillers pick up parts for compressor.
8:55 - 12:00	Drilling open hole 10"Ø 27 to 70'. Hit orange/red-brown clay/silt at 55' (similar strata to strata in TW11 and TW12). Weathered basalt and sand/clay at 55 to 60' - no water.
12:00 - 1:00	Lunch.
1:00 - 3:50	Drilling 10"Ø open hole 70 to 105'. Lose circulation at 93/94'. Return at 96/97' - hole making 5 gpm - water is warm, 18°C (65°F), F = 7.1 mg/l. Loose circulation again at 99'. No return 99 to 105'. May be washing out sandy zone between 55 to 60'.
3:50 - 4:05	Pull out drill string. Sound hole - hole caved to 90' below ground level. Water level 87.3' below ground.
4:05 - 5:05	Pick up 80' of 8"Ø casing from yard.
5:05 - 6:30	Set 8" casing to 30' - casing has problems getting through 10" casing, since 8" casing has drive shoe on.

Geolograph malfunctioned all day.

HISTORY OF HOLE

TW25

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/20/84

8:00 - 10:20	Push 8" casing through construction in 10" pipe using vibratory downhole hammer. Set 105'5" 8" casing in hole. Casing is set to approximately 103' below surface.
10:20 - 10:45	Run drill string with 8" bit into hole.
10:45 - 11:50	Drilling 8"Ø open hole 105 to 117'. 1 to 2 gpm warm water.
11:50 - 1:25	Lunch.
1:25 - 4:30	Drill 8"Ø open hole 117 to 167'. Hit orange/red clay layer at 132', then loose fractured basalt and vesicular basalt at 134 to 146'. Water much cooler (10°C). Increase in air-lifted flows to 50 gpm. Zone caves a little, but worked bit through. Fluoride sample from 137' = 6.1 mg/l.

DATE: 10/22/84

9:20	Depth to water = 89.4' below ground level.
9:20 - 12:05	Drill 8"Ø open hole 167 to 188'. Mainly fresh grey basalt, possibly weathered zones at 174 and 182' - reddish tinge to water, but no change in chemical parameters.
12:05 - 1:30	Lunch.
1:30 - 3:45	Drill 8"Ø open hole 188 to 250'. Mainly fresh grey basalt, thin weathered zones at 194', 218' and 235'. Water reddish in these zones - no change in water quality though. Water sample from 248' - F = 2.7 mg/l.

HISTORY OF HOLE

TW25

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/23/84

	Depth to water = 87.9' below ground.
7:30 - 8:30	Pull out 8" drill string from 250'.
8:30 - 10:00	Log hole using Monsanto's logger - natural gamma and resistivity.
10:00 - 11:55	Place bentonite pellets (150 lbs) 248 to 244.8'. Add 29 gals pea gravel at 244.8 to 236.9'.
11:55 - 12:50	Lunch.
12:50	Set 1x5' 20 slot PVC screen - threads teflon wrapped. 12x20' blank PVC pipe - centralizers every 60'. Run sounder - can not get sounder past 61 m (200'). Sounder also has trouble passing 134'. Remember drive shoe has not been cut off casing. Pull out PVC and well screen - screen has some bentonite on bottom - probably picked up from sides of borehole. Sound hole to 236.3' - has not filled up.
4:15	Run casing cutter to 80'. Pressurize and rotate for 15 to 20 mins.
5:00	Pull out casing cutter. Sound hole and add 2 gals gravel to 236'. Sound hole - hole appears to narrow at 133.5' below ground - sounder has bentonite on it from this depth.
5:25	Run 8" bit and guide to 140' rotating slowly through narrow zone.
5:45	Pull out 8" bit and guide.
6:00	Check guide and bit - both have bentonite on them. Sound hole - depth now 234.2' below ground. Hole has therefore filled up approximately 2', probably with bentonite that was stuck to the sides of the hole. Add 2 gals gravel to bring level to 233.5'. Since zone to be screened is 237 to 231', 3' of the zone is still open.
6:30 - 7:30	Reset PVC pipe and screen - pipe appears to settle down through soft material at bottom of hole. Have problems running sounder to bottom of hole - hanging up at 134 and 200'.

HISTORY OF HOLE

TW25

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/24/84

7:00 - 8:25	Pull out PVC pipe and screen. Sounded depth to bottom of well 235.4'. Will cement hole and try to set screen higher due to possible bentonite in screened section.
8:25 - 9:00	Run 11x21' tremie pipe (231').
9:00 - 9:25	Wait for cement truck. Cement truck brings 60 gals cement (11 bags) + 60 gals water. Add 5 lbs $CaCl_2$ + 5 lbs bentonite + a little Flocele.
9:25 - 10:05	Pump cement to bottom of hole - should fill up to about 210'.
10:05 - 10:55	Clean up tremie pipe and cement pump. Move off well to allow cement to set.

DATE: 10/29/84

11:00	Move back onto hole and try to pull 8" steel casing - will not move, although cut back at 80'. Move off hole.

DATE: 10/30/84

p.m. 3:05	Move back over hole.
3:20 - 4:10	Run casing perforator between 60 and 95' inside 8" steel casing - perforations about 1/4"x1" every 1 to 2". Can not run perforator below 95' - appears to be tight around 8" pipe below this depth. This leaves 95 to 105' casing unperforated. Bottom approximately 185' below ground - feels mushy. Perforated 2 runs at 180° to each other.
4:10	Run 8" drill string into hole to clean out constriction at 132'. Fine brown sand returns during clean up of hole. Washed hole 'til 5:45 - water eventually clears up. Pull back 8" drill string to 130'.

HISTORY OF HOLE

TW25

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/31/84

7:00 - 7:25	Drillers picked up PVC.
7:25	Ran drill stem to bottom of hole - seems open.
7:55	Pull out of hole - hole sounded to 193.6' - 2.5' stick up = 191.1' below ground level. Hole squeezing at about 134 to 137' below ground level.
7:55 - 8:25	Run 8" casing cutter to 50' and cut steel casing - sound hole to 191' below ground.
8:25 - 10:15	Set 10' 20 slot PVC well screen + 9x20' blank PVC pipe + 1x10' blank PVC pipe - 4"Ø threads teflon wrapped.
10:15 - 12:00 and 1:00 - 1:45	Gravel pack screen to 179.2' with 25 gals gravel and 150 lb bentonite pellets at 179.2 to 176.1'. Bentonite appears to be hanging up at about 33 m (108') - 3' s/u = 105'.
1:45 - 2:00	Run 1" tremie pipe to 165'.
2:00 - 2:45	Wait for cement (Parsons) - 400 gals water and 73 bags cement.
2:45	Add 12.5 lbs Flocele, 50 lbs bentonite and mix 25 mins.
3:50	Cement pumped into hole.
4:30	Cleaning out equipment. Grout appears to be at least 37 m (121') below casing, 121.4' - 2.5' = 118.9'. Depth to water outside 4" PVC is 18 m (59'). Grout has displaced water upwards.
4:45	Move off hole to TW28 site (northwest corner).

HISTORY OF HOLE

TW25

GEOLOGIST: D. Banton / M. Shaleen DATE: 11/03/84

Evening of November 2nd - moved back and set up on TW25.

7:00 - 7:20	Run 1"Ø tremie pipe to 106' below ground level - bottom is solid.
7:45	Ordered 400 gals water + 73 bags cement from Parsons.
7:45 - 9:10	Wait for cement truck.
9:10 - 9:30	Add 50 lbs bentonite powder and 12.5 lbs Flocele to cement and mix 15 mins.
9:30 - 10:20	Pump approximately 200 gals cement into TW25 and use the remainder to top up TW26.
10:20 - 10:40	Cleaning out equipment - tremie pipe and cement pump.
10:40 - 12:00	Try to pull 8" casing (had been cut at 50') with top head - casing would not move. Welded on additional length of 8" casing, vibrated casing with downhole hammer and pulled with top head - casing was stuck solid.

Considered it uneconomical to try to pull casing with casing hammer, since too much time would be expended setting up the equipment to pull the casing.

WELL DEVELOPMENT - TW25

The well was developed on November 5th, 1984. One inch diameter tremie pipe was set to 160 ft below ground. The well was developed with compressed air; however, the well recovered only very slowly. Ony one water sample was obtained:

T = 9.5°C

C = 1350 μmhos/cm

pH = 6.46 (No fluoride samples were run)

Occasional water levels were recorded following the removal of the 1 inch pipe:

DATE	TIME	DTW		Comment
		(m)	(ft)	
04/11/84	11:30	28.25	92.68	Day before developing.
05/11/84	10:05	27.31	89.59	With 1" pipe in well.
05/11/84	10:40	46.82	153.60	Pulled out 1" pipe at 10:20.
05/11/84	13:02	37.83	124.11	

The water level in TW26 declined 0.06 ft during the "development" of TW25. The water level in TW27 apparently rose 0.02' during the same period.

TW 26

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

WELL ~~PIEZOMETER~~ INSTALLATION DATA

Figure

BOREHOLE TW26

HOLE DIAMETER 10" 0-97'
8" 97-142'

REMARKS:

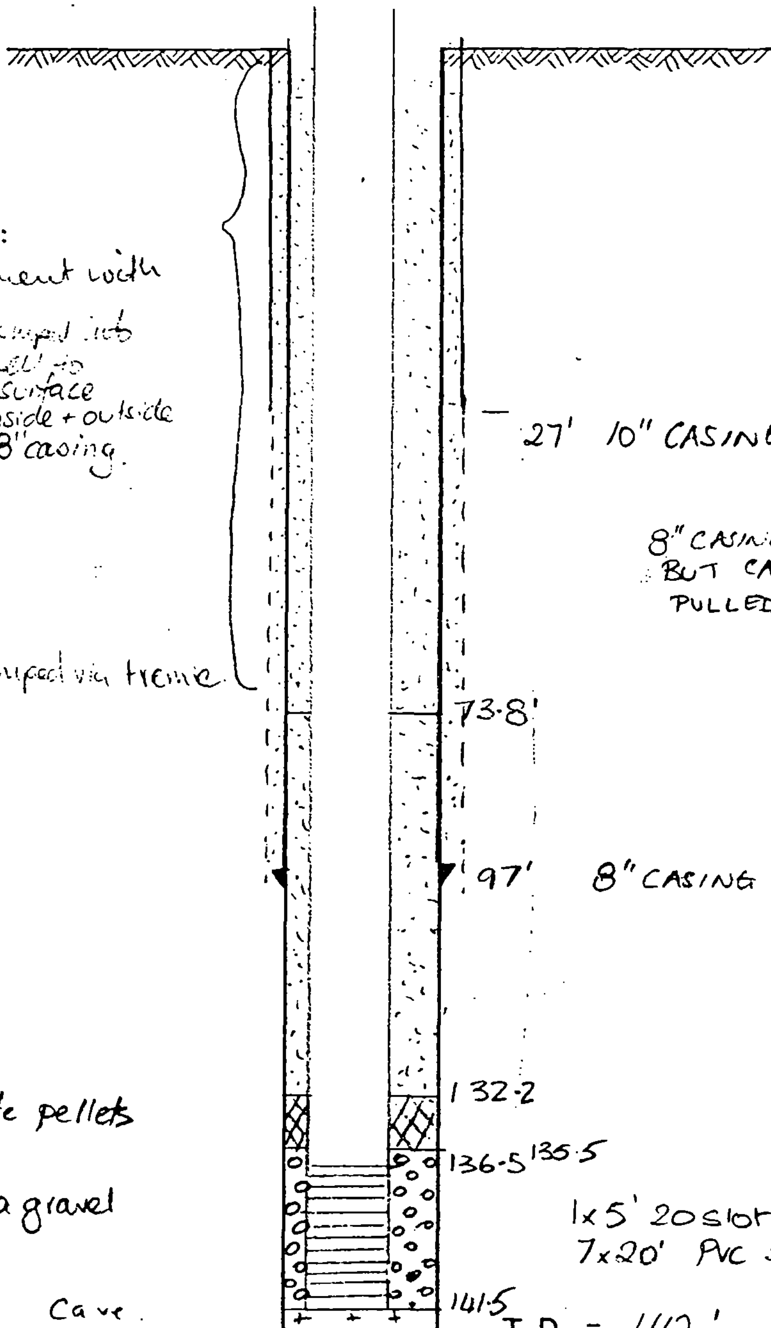
Approx 200gals cement with
36bags cement
127lbs flocele
25lbs bentonite
pumped into well to surface inside + outside 8" casing.
11/3/84

Cement Grout - pumped via tremie
73 bags cement
400gals water
50lbs bentonite
12½ lbs flocele

200lb bentonite pellets

15 x 2gal pails pea gravel

Cave.



PROJECT NO. DRAWN REVIEWED DATE

HYDROGEOLOGIC LOG

DRILLHOLE No. TW26
Sheet 1 of 2

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E ....
N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

Depth (ft)	(1) (2) * Lithology	Other (6) Pen. Rate mins/ft	Comments
Ground Surface			
0–27	Grey silty GRAVEL and COBBLES (FILL)		
27–32	Fresh grey BASALT		
32–39	Brown/black silty SAND and weathered basalt	4	
		3	
39–50	Fresh grey BASALT	12	
		8.5	
50–56	red/brown fine SAND	0.5	loosing circulation
56–59	Fresh grey BASALT	1.5	
59–61	red/brown fine SAND		
61–90	Fresh grey BASALT	7	
		9	
		7	
		5	
		8	
		5	

Column headings: (1) (2)* Lithology; (2) (3) Completed Construction; During Drilling: (2) Depth (m) [ft], (2)(4) Water Level (m) [ft], (5) Water Flow (l/s) [ft.], (6) Other Pen. Rate [mins/ft]; After Drilling: (2)(7) Water Level (m), Permeability (8): (2) Depth (m), Method, Value (cm/s); Comments.

Completed Construction: 10" to 27; 8"; 6"; ▼27

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling
Date started: 24th October 1984
Date finished: 27th October 1984
Logged by: DB/MS
Checked by: ....
Date: ....

\# NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW26
Sheet 2 of 2

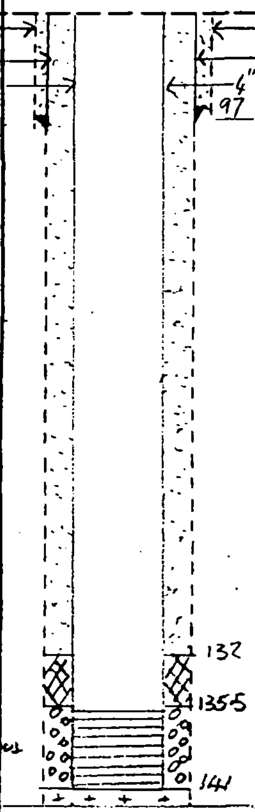
Project ....
Type of drilling ....
Rig ....
Drilling fluid ....

Coordinates: E ....
N ....
Angle from horizontal ....
Bearing .... °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ....

Job No.

(1) (2)* Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	During Drilling (2)(4) Water Level ~~(m)~~	During Drilling (5) Water Flow ~~(L/s)~~	During Drilling (6) Other pen. rate	After Drilling (2)(7) Water Level ~~(m)~~	After Drilling Permeability (8) (2) Depth (m)	After Drilling Permeability (8) Method	After Drilling Permeability (8) Value (cm/s)	Comments
90 Cont'd		ft	ft	gpm	mins/ft	T°C	C uS/cm	pH	eH (mV)	
92	10" 8" 4"				2.5					loose circulation at 92'
98	97									
100 Fresh grey BASALT 108		107		10-20	/	10	1300	7.41	+126	Cuttings return after casing set.
110 Light Brown fine SAND 110										
Fresh grey BASALT 119						9	1300	7.28	+138	
					5	10	1300	7.45	+149	
120 Brown fine SAND and faintly weathered vesicular BASALT 123					2	9.5	1325	7.44	+141	
Fresh grey BASALT.					5	9	1300	7.52	+130	
130 131					3					
Red/orange SILT, trace fine sand 134	132					—	—	—	—	
Red/brown faintly weathered vesicular BASALT and scoriacious	135.5				1	8	1200	7.22	+122	
140 CINDERS	141	142	87.5	50+	1	8	1250	7.36	—	
End of Borehole										



Contractor ....
Date started ....
Date finished ....

Logged by ....
Checked by ....
Date ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW26

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/24/84

11:00	Move and set up on TW26.
11:15 - 11:45	Weld on 10" pipe on outside of 10" casing as drive shoe.
11:45 - 11:55	Drilled and drove 10" casing to 5'. 1st length 10" = 10'10".
11:55 - 12:55	Lunch.
12:55 - 2:30	Drove 10" casing to 27' through slag. 2nd length 10" = 20'. Cut off 3' casing at ground level.
2:30 - 6:10	Drilling 10"Ø open hole 27 to 68'. No water encountered. Problems with circulation at 55' in fine sand.
6:10 - 6:45	Drillers repair top head motor seals.

DATE: 10/25/84

7:00 - 10:05	Drilling 10"Ø open hole 68 to 97'. Loose circulation at 92'. Damp cuttings at 95'.
10:05 - 11:00	Pull out drill stem - drillers leave to pick up welding rods.
11:00 - 12:00	Start setting 8" casing. Total length+shoe = 140'. 6' cut-off totalling 98'.
12:00 - 12:55	Lunch.
12:55 - 4:30	Setting 8" casing - difficult getting 8" casing past 37' - appears rock has lodged in hole - run 8" drill string inside casing to remove blockage - hook up downhole hammer bit to vibrate casing through blockage. Hook up casing hammer to drive last 20'. 8" casing set to 97'.
4:45 - 6:40	Drilling 8"Ø 97 to 127'. Making 10 to 20 gpm below 100'. Water has a lot of fine sand - not warm though.

HISTORY OF HOLE

TW26

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/26/84

7:00 - 7:50	Drilling 8"Ø open hole 127 to 142' - hit orange/red silt at 130', then cinders and vesicular basalt at 134', making >50 gpm.
7:50 - 8:20	Pulled out drill string and set up for logging hole.
8:20 - 9:30	Logging hole using Monsanto logger, natural gamma and resistivity.
9:30 - 10:00	Ran casing cutter to 40', rotated and pressurized cutter.
10:00 - 12:00	Setting 4"Ø PVC pipe and screen, set 1x5' 20 slot screen + 7x20' blank PVC pipe.
12:00 - 1:00	Lunch.
1:00 - 2:45	Gravel packed screen with 15x2 gal pails gravel.
2:45 - 3:15	Mary searced for heavier weight for depth sounder.
3:15 - 5:00	Placed 4x50 lb pails bentonite over gravel pack.
5:00 - 5:15	DB goes to order cement - plant already closed.
5:15 - 5:30	Run 1"Ø tremie pipe to 123' below ground level. Depth to water in well = 27.15 m (89.07'), depth to water outside well = 27.14 m (89.04').

TW 27,

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

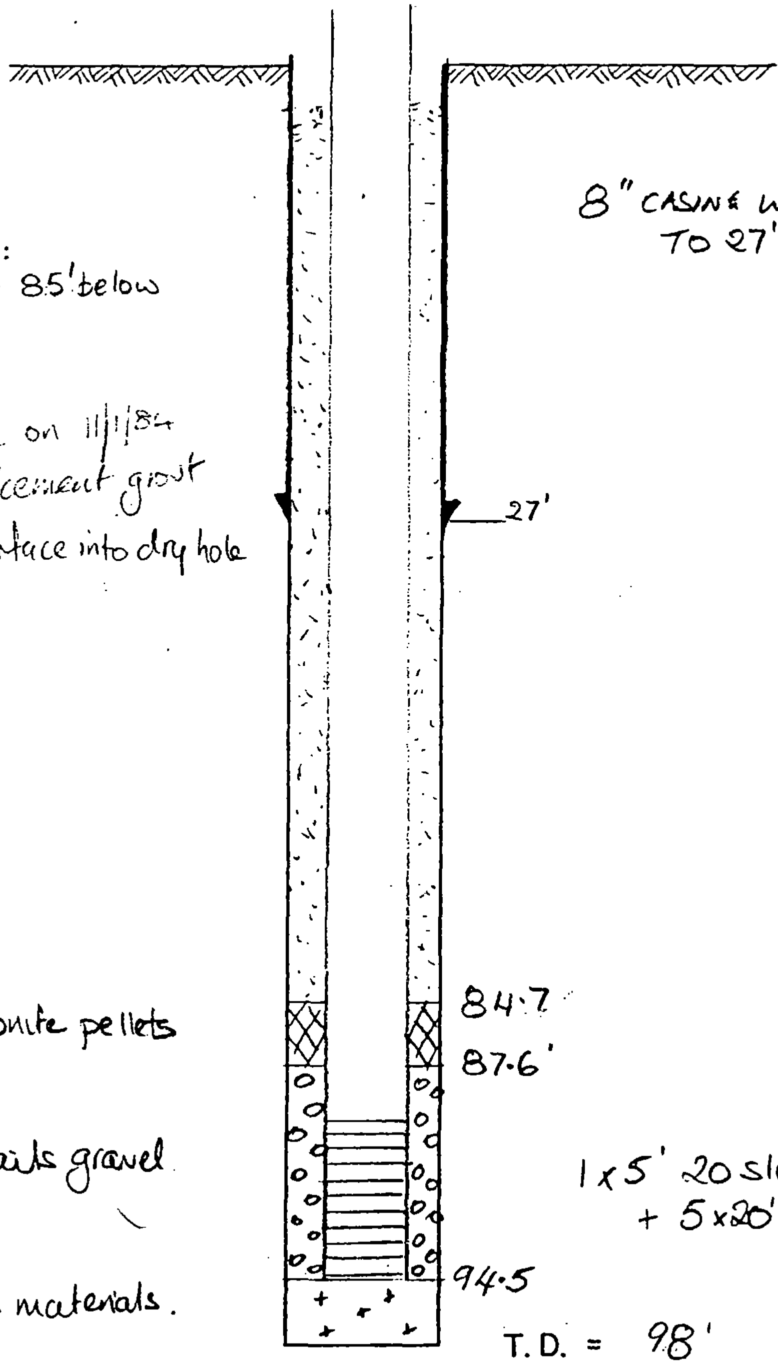
BOREHOLE TW27

HOLE DIAMETER 8" 0-98'.

8" CASING WITH DRIVE SHOE TO 27'.

REMARKS:
Water level approx at 85' below ground.

Grouted to surface on 11/1/84 with 1 yard sand/cement grout mixture poured from surface into dry hole



50 lb bentonite pellets

8 x 2 gal. pails gravel

Caved materials.

1 x 5' 20 slot PVC screen + 5 x 20' blank PVC pipe.

T.D. = 98'

PROJECT NO. .... DRAWN .... REVIEWED .... DATE ....

Golder Associates

HYDROGEOLOGIC LOG

DRILLHOLE No. TW27
Sheet 1 of 2

Job No.

Project: MONSANTO GROUNDWATER STUDY

Type of drilling: ROTARY

Rig: SCHRAMM T-64

Drilling fluid: AIR/WATER

Coordinates: E .... N ....

Angle from horizontal: 90°

Bearing: — °Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole: MONITORING WELL

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(L/s)~~ gpm	(6) ~~Other~~ Pen. Rate min/ft	After Drilling: (2)(7) Water Level (m) T°C	Permeability (8): (2) Depth (m) C µ/cm	Method pH	Value (cm/s) eH	Comments
Ground Surface										
0–24: Grey Silty GRAVEL (FILL)	8" (hole); 6" (casing)									
24–27: brown gravelly CLAY	casing to 27									
27–38: Brown silty SAND and weathered BASALT					1.5					
38–59: Fresh grey BASALT					4					
					8					
					6					
					7					
59–65: Red/brown fine SAND trace silt					1					
					1					
65–67: Fresh grey BASALT										
67–79: Red/brown fine SAND and weathered BASALT.					2					
					1					
79–90: Fresh grey BASALT	84.5				6					
	87.5				4.					
					9					

Depth scale (ft): 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling

Date started: 29th October 1984

Date finished: 30th October 1984

Logged by: DB/MS

Checked by: ....

Date: ....

\# NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

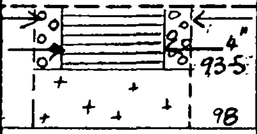
DRILLHOLE No. TW27
Sheet 2 of 2

Project ....
Type of drilling ....
Rig ....
Drilling fluid ....

Coordinates: E ....
N ....
Angle from horizontal ....
Bearing .... °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ....

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~	During Drilling: (2) (4) Water Level ~~(m)~~	During Drilling: (5) Water Flow ~~(l/s)~~	During Drilling: (6) ~~Other~~ Pen. Rate	After Drilling: (2) (7) ~~Water Level (m)~~	After Drilling: ~~Permeability (8) (2) Depth (m)~~	After Drilling: ~~Method~~	After Drilling: ~~Value (cm/s)~~	Comments
90 Contd		ft	ft	gpm	min/ft	T°C	µS/cm	pH	eH	
92		8"			9					lost circulation at 92'
					2					
98'		98	83.7							
100 End of Borehole										

Contractor ....
Date started: ....
Date finished: ....
Logged by: ....
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW27

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/29/84

p.m. 1:25	Move over and set up on TW27. Weld on drive shoe to 8" casing.
3:05	Hook up casing hammer.
3:10	Started drilling and driving 8" casing. Casing + shoe 8.5' + 20' = 28.5'. Weld on 20' 8" casing. Drilled through slag to 24', then gravelly clay. Bedrock at 27'. Casing driven into bedrock.
6:20	Drilled 8" open hole to 48' - no water.

DATE: 10/30/84

7:00	Start drilling from 48'.
10:25	Drilled to 98' by 10:25. Loose circulation at 92' - 92 to 97' faster drilling, weathered zone. No return of water or cuttings. Depth to water = 86.35' - 2.6' s/u = 83.75' below ground.
10:25 - 10:55	Pull out drill string - prepare to log hole.
10:55 - 11:50	Logging hole using Monsanto equipment - natural and resistivity.
11:50 - 12:50	Lunch.
12:50 - 3:05	Hole caves about 4' before screen set. Screen 1x5' 20 slot PVC at 94 to 89'. Gravel pack with 8x2 gal pails gravel at 94 to 87.6'. 50 lb bentonite pellets at 87.6 to 84.7'. Cut off 8" steel casing at 1.5', therefore casing at 27'.

DATE: 11/01/84

Grouted to surface with 1 yd sand/cement mixture poured from surface into dry hole.

WELL DEVELOPMENT - TW27

The well was developed on November 5th, 1984. One inch diameter tremie pipe was set to just above the bottom of the well (94 ft), and the well developed for about 1 hour at 1 gpm. The water was initially red/brown, containing a lot of fine sand; however, the water was clear following development.

Chemical parameters from the discharged water are given below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	Eh (mV)
20	7	1100	7.39	72
40	8	1200	7.57	71
65	7	1200	7.70	72

Fluoride sample from water after 35 mins gave F = 5.4 mg/l.

Water levels in both TW25 and TW26 were recovering during the development of TW27.

HISTORY OF HOLE

TW26

GEOLOGIST: D. Banton / M. Shaleen DATE: 10/27/84

8:00	Depth to water in well = 27.40 m (89.89')
8:00 - 8:15	Wait for cement truck to arrive.
8:15 - 9:00	Add 12-1/2 lbs Flocele + 50 lbs bentonite to 400 gals water + 73 bags cement, mix for 20 to 30 mins.
9:00 - 9:45	Pump grout into hole annulus.
9:45 - 10:10	Clean out cement mixer and 1" tremie pipe.
10:30 - 11:45	Tried to pull out 8" casing - would not move. Attached down-hole hammer to top head and vibrated casing - would only move down a few inches but not up. Casing probably locked in hole by rocks. Decide to abandon casing.
	Sound cement to 73.8' below ground inside 8" casing.

DATE: 11/03/84

Added 36 bags cement with 200 gals water + 7 lbs Flocele + 50 lbs Bentonite powder to inside and outside 8" casing (remainder of mix was used to grout TW25). Time adding cement was charged to TW25. Grout pumped into hole from surface using 1" diameter hose.

WELL DEVELOPMENT - TW26

The well was developed on November 5th, 1984. One inch diameter tremie pipe was set to a depth of 120 ft and the well airlifted at a rate of about 10 gpm for approximately 1 hour. The water had an orange/brown colour during most of the development.

Chemical parameters of the discharged water are shown below:

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH	Eh (mV)
5	8	1225	7.08	69
18	8	1275	7.21	58
35	9	1275	7.34	65
45	8.5	1300	7.35	70
60	8	1300	7.49	76

Fluoride sample from water after 35 mins gave F = 0.81 mg/l.

The water level in TW27 drew down 0.07' during the development of TW26. TW25 was still recovering.

TW 28

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

PIEZ~~OMET~~ER WELL. INSTALLATION DATA

Figure

BOREHOLE TW28

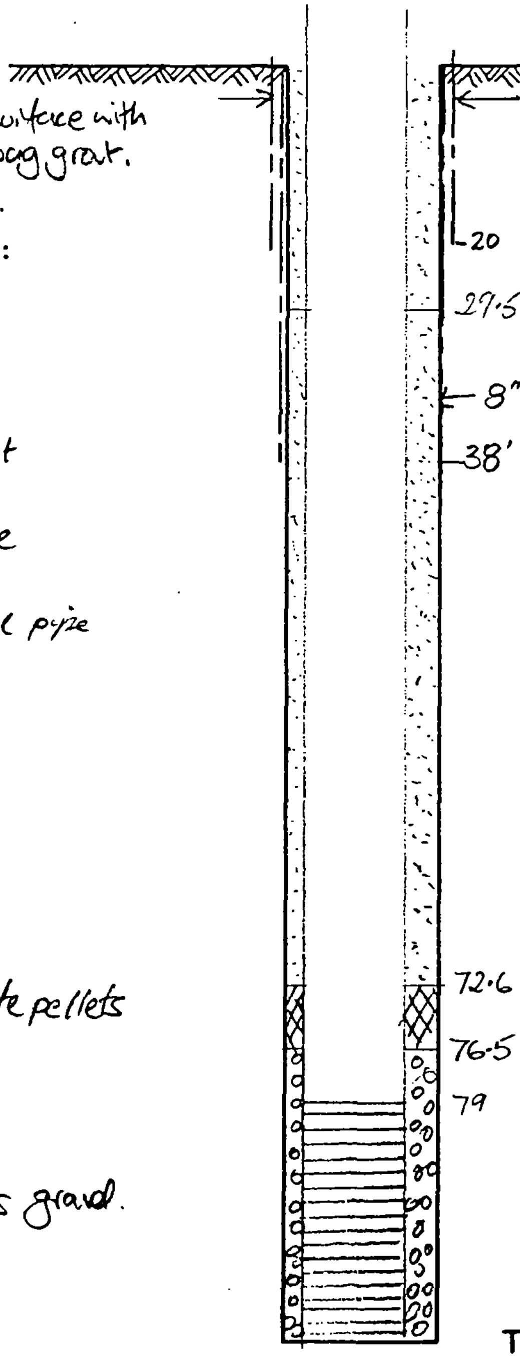
HOLE DIAMETER 10" 0-38'
8" 38-89'

Hole grouted to surface with approx 1 yard 9 bag grout. 11/8/84.

REMARKS:

10" casing set to 20' - pulled out when hole grouted.

8" casing (no shoe) set to 38' - pulled out when hole grouted.



73 bags cement
400 gals water
50 lbs bentonite
12½ lbs flocele
pumped via tremie pipe

3x50 lbs bentonite pellets

21x2gal pails gravel.

1x 10' 20 slot screen PVC
+ 4x20' PVC blank
+ 1x10' PVC blank.

T.D. = 89 FT.

DATE .... REVIEWED .... DRAWN .... PROJECT ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW28
Sheet 1 of 1

Job No.

Project: MONSANTO GROUNDWATER STUDY

Type of drilling: ROTARY

Rig: SCHRAMM T-64

Drilling fluid: Air/Water

Coordinates: E .... N ....

Angle from horizontal: 90°

Bearing: — °Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole: MONITORING WELL

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth (m) ft	(2)(4) Water Level (m) ft	(5) Water Flow (l/s) gpm	(6) Other Pen. Rate min/ft	After Drilling: (2)(7) Water Level (m) T°C	Permeability (8): (2) Depth (m) Cond	Method pH	Value (cm/s) eH	Comments
Ground Surface.										
Grey GRAVEL (FILL) 4	10" / 8" / 4"									
Brown Silty CLAY trace gravel 22	20									
Fresh grey BASALT 26										
Sl. to mod. weathered grey BASALT with Clay (loose) 36					1					
Fresh grey BASALT 45	38				2					
					3	10.5	825	7.77	—	Water sample from 50' F= 0.60 mg/l
Fresh to faintly weathered red/grey fractured BASALT 50					3	9.0	800	7.69	—	
						8.5	600	7.58	140	
Fresh grey BASALT 75					5	8.5	800	7.66	230	
					7	9.5	810	7.74	162	
					7	9.5	850	7.70	252	
					11					
	72.5					10	825	7.64	235	
Red/brown loose Scoriacious CINDERS and vesicular BASALT	76.5				4					
					2.5					
					2.5					
	89	89	36	50		7	800	—	—	
90' End of Borehole 89										

Depth scale (lithology column): 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling
Date started: 1st November 1984
Date finished: 6th November 1984
Logged by: DB/MS
Checked by: ....
Date ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW28

GEOLOGIST: D. Banton / M. Shaleen DATE: 11/01/84

7:00 - 9:40	Wait for Monsanto to build pad to drill on.
9:40 - 10:00	Move and set up rig over hole location.
10:00 - 10:25	Drill 10"Ø open hole 0 to 21'. Run 21' 8" casing s/u = 1'. Bedrock at 22', slag at 0 to 5', and silty clay at 5 to 22'.
10:25 - 12:15	Drilling 8"Ø open hole 21 to 58' - hit water at 46' making 10 to 15 gpm. F = 0.60 mg/l.
12:15 - 1:15	Lunch.
1:15 - 4:20	Drilling 8"Ø 58 to 89' - hit cinder zone at 75' making 50 gpm - hole caving and loose.
4:20 - 5:00	Pull out 8" drill string and sound hole - hole has caved at 32' in weathered basalt section - probably disturbed by all the water during drilling.
5:00 - 5:45	Pull out 8" casing. Push in 21' 10" casing s/u = 1'. Drill 10"Ø open hole to 39' (reaming). Push 42' of 8" casing into hole s/u = 4'6" , therefore casing pushed to 37'6".

DATE: 11/02/84

7:00	Run 8" drill string to 39' and clean out hole to 89'. Hole does not cave in cinder zone.
8:00	Move off hole to drill TW29 and leave hole to be logged by W.S.U.

HISTORY OF HOLE

TW28

GEOLOGIST: D. Banton / M. Shaleen DATE: 11/04/84

8:45 - 9:50 Washington State University logs TW28 with S.P., resistivity, caliper, natural gamma, gamma-gamma and neutron-neutron.

9:50 - 10:45 Golder logs TW28 using Monsanto logger - run S.P., resistivity, and natural gamma.

DATE: 11/05/84

p.m.
3:10 Set up over TW28 with drill rig.

3:10 - 6:20 Set 1x10' PVC 20 slot screen to 89' + 4x20' PVC blank pipe + 1x10' PVC blank pipe. Joints teflon wrapped and two centralizers. Backfilled to 76.5' with 21x2 gal pails gravel. Added 100 lbs bentonite pellets to 75.5' - hole diameter probably much larger here since still in cinder zone.

DATE: 11/06/84

7:00 - 12:30 Add 50 lbs bentonite pellets to 72.6' (3' seal). Order 73 bags cement in 400 gals water from Parsons. Add 50 lbs bentonite powder and 12-1/2 lbs Flocele - mix for 15 to 20 mins. Run tremie pipe to 60' below ground and pump in grout. Sound grout to approximately 30' following pumping. Pull out 1" pipe, pull out 21' 10" casing and pull out 39' 8" casing. No casing left in hole.

DATE: 11/08/84

Grout to surface with 1 yd 9 bag grout brought by Parsons.

WELL DEVELOPMENT - TW28

TW28 was developed for 5 mins with compressed air on November 7th, 1984. Development was stopped since the water was washing away the soil from around the well. The well produced 30 to 50 gpm during development with 1 inch diameter pipe set at 60 ft introducing compressed air. The water level in TW29 declined 0.01 m (0.03 ft) during the 5 min development period. One water sample was analyzed; the results are shown below:

T = 8°C

C = 900 μmhos/cm

pH = 6.78

Eh = +219

F = 0.35 mg/1

The well was developed for a second time on November 11th, 1984, using the portable compressor. The air hose was set to a depth of 89 ft and the well was airlifted for 20 mins at a rate of about 50 gpm. No measurements of water levels or chemical parameters were recorded during or after development.

TW 29

i) Schematic Test Well Completion

ii) Field Borehole Log

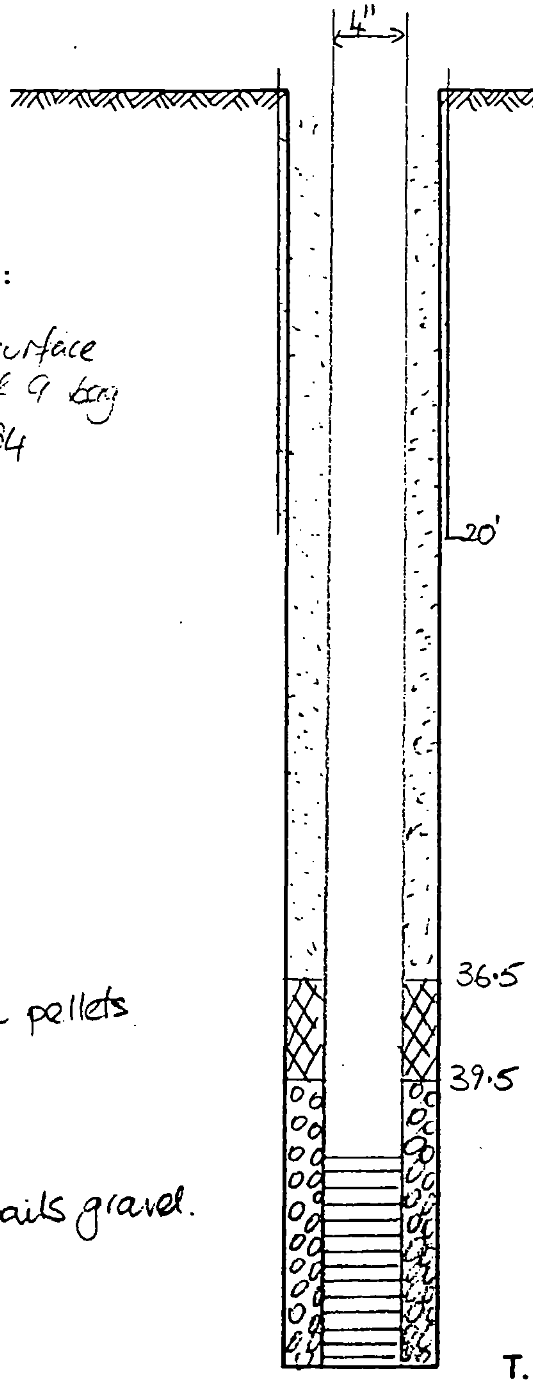
iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW29.

HOLE DIAMETER 0-47' 10".



REMARKS:

Hole grouted to surface with 1yard of 9 bag grout 2/11/84

21' of 10" CASING IN HOLE
S/U = 1'

100 lbs bentonite pellets

12.5 x 2gal. pails gravel.

1x5' 20 slot PVC screen.
+ 2x20' blank PVC
1 x 10 blank PVC

T.D. = 47'

DRAWN .... REVIEWED .... DATE .... PROJECT

HYDROGEOLOGIC LOG

DRILLHOLE No. 7N39
Sheet 1 of 1

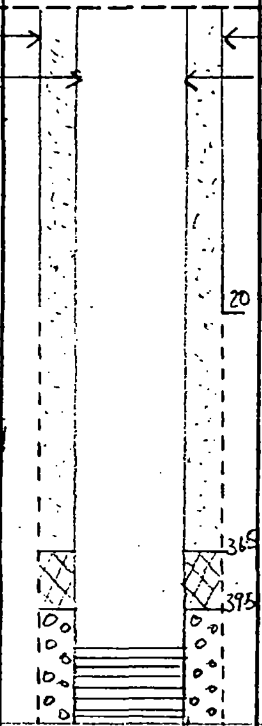
Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: Air/water

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	During Drilling (2)(4) Water Level ~~(m)~~	During Drilling (5) Water Flow ~~(L/s)~~	During Drilling (6) ~~Other~~ Pen. rate	After Drilling (2)(7) Water Level (m)	Permeability (8) (2) Depth (m)	Permeability (8) Method	Permeability (8) Value (cm/s)	Comments
Ground Surface		ft	ft	gpm	min/ft	T°C	C umho/cm	pH	eH	
Grey GRAVEL (FILL)	10" / 4"									
Brown Silty CLAY trace gravel (10)	20									
20 — 21										
Fresh grey BASALT — 27					1					
Slightly to moderately weathered brown grey BASALT with brown clay (30) — 37	36.5				1					
Fresh grey BASALT (40) — 45	39.5				2					damp at 41'
					5					
47		45	36	20-30	2.5	10	800	7.63		
End of Borehole (50)										
Faintly weathered grey to red/brown BASALT, fractured.										



Contractor: Andrew Well Drilling
Date started: 2nd Nov 1984
Date finished: 2nd Nov 1984
Logged by: DB/MS
Checked by: ....
Date: ....

\# NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW29

GEOLOGIST: D. Banton / M. Shaleen DATE: 11/02/84

8:00	Move and set up on TW29.
8:15 - 8:55	Drill 10"Ø open hole to 20' - encountered fill at 0 to 5', sandy clay and occasional gravel at 5 to 20'.
8:55	Push 21' of 10" casing to 20' - casing stick up = 1'.
8:55 - 10:45	Drilling 10"Ø open hole 20 to 47' - hit damp basalt at 41', making 20 to 30 gpm at 45'. Depth to water about 39'.
10:55 - 11:35	Logging hole using Monsanto logger (natural gamma and resistivity).
11:35 - 12:30	Set 5'x 20 slot PVC screen to 47' + 2x20' blank PVC + 1x10' blank PVC - threads teflon wrapped. Add 12.5 pails gravel (2 gal each) to 39.5'. Add 100 lbs bentonite pellets to 36.5'.
12:30	Move off hole.
3:00	Parsons cement truck delivers 1 yd of 9 bag grout (sand and cement), about 10 lbs of bentonite added and grout poured into hole - hole is dry.

WELL DEVELOPMENT - TW29

TW29 was developed on November 7th, 1984. One inch diameter pipe was set to a depth of 39' below ground level and the well developed with compressed air for approximately 1 hour. Airlifting produced only 1/2 gpm due to the low submergence. Chemical measurements on the discharged water are given below. Water levels in TW28 were monitored using the metric probe (P3) during development. No response observed in TW28.

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH	Eh (Mv)
3	6	800	-	+164
20	4.75	775	7.36	+173
40	5	775	7.48	+178
63	5	775	7.48	-

F = 0.48 mg/1.

TW 30

i) Schematic Test Well Completion

ii) Field Borehole Log

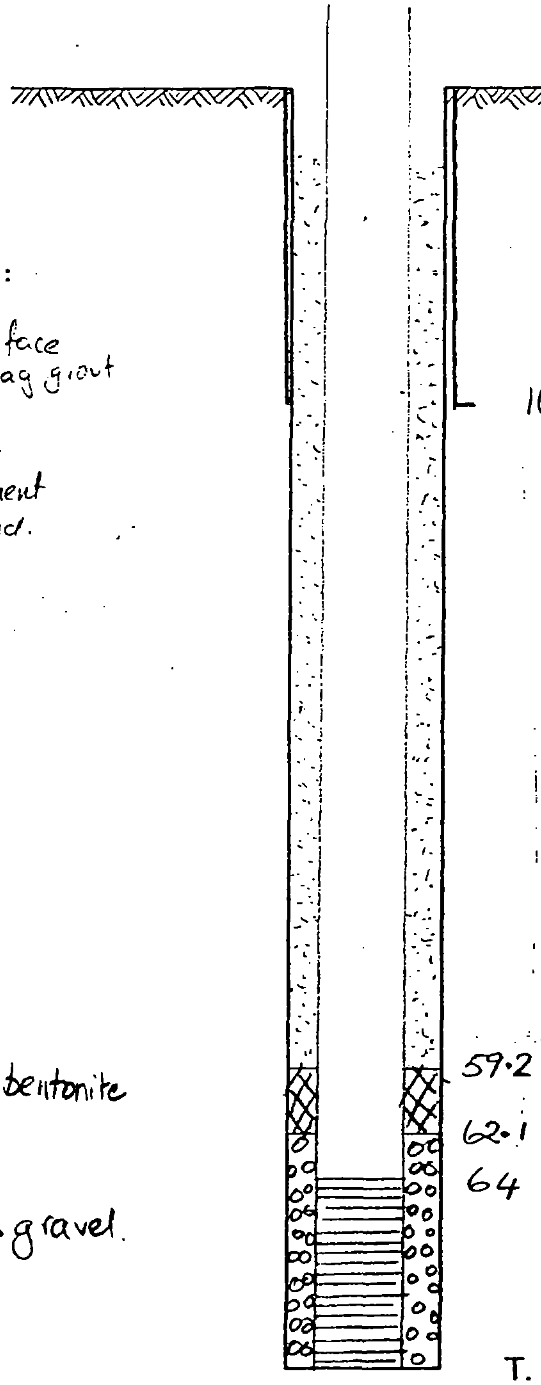
iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW 30

HOLE DIAMETER 8" 0-69'



REMARKS:

Grouted to near surface with 1 yard 9 bag grout 11/8/84

1 yard = 48 gals water
9 bags cement
2200 lbs sand.

1x 50 lb pail bentonite

13 x 2 gal pails gravel

1 x 5' 20 slot PVC screen
+ 3 x 20' PVC blanks
+ 1 x 10' PVC blank.

T.D. = 69 FT.

PROJECT NO. DRAWN REVIEWED DATE

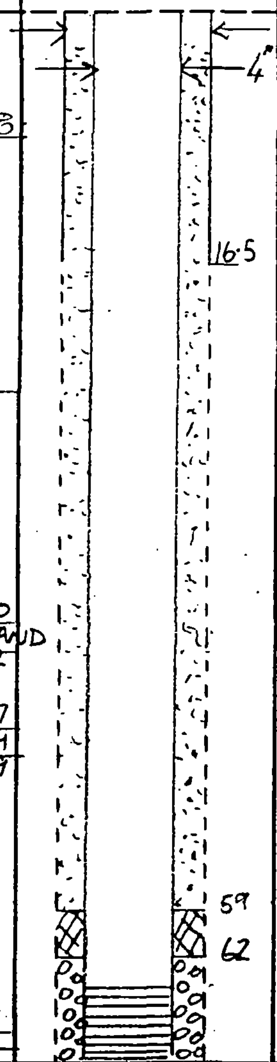
HYDROGEOLOGIC LOG

DRILLHOLE No. TW 30
Sheet 1 of 1

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER
Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth
Reference elevation: ....
Elevation type: surveyed ☑ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No. ....

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) ~~Other~~ Pen. Rate mins/ft	After Drilling: (2)(7) Water Level (m)	Permeability (8): (2) Depth (m)	Method	Value (cm/s)	Comments
Ground Surface										
Grey silty GRAVEL (FILL) 0–8										
10 Brown silty CLAY 8–~24										
20										
Fresh grey BASALT occ. vesicular (30)					2					
					3					
40 Red/brown silty SAND 40–42					2					
Fresh grey BASALT 42–47					2					
Red/brown silty CLAY 47–49										
50 Fresh grey BASALT (vesicular 49–57') 49–67					2					
					1.5					
60					2.5					Water sample from 68' F = 2.9mg/l.
					1.5					
67		69	61	10–15	5					
70 End of Borehole										



...own ...y weathered ...icular ...ALT and ...ERS

Fresh grey BASALT

Contractor: Andrew Well Drilling
Logged by: DB
Date started: 8th November 1984
Checked by: ....
Date finished: 8th November 1984
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale: ....

HISTORY OF HOLE

TW30

GEOLOGIST: D. Banton / M. Shaleen DATE: 11/08/84

8:30	Set up over hole and started drilling 8"Ø open hole. At 0 to 8' encountered fill, gravel, sand and silt, and at 8 to 25' encountered brown silty clay.
9:00	Bedrock at 25'.
9:10	Pull out 8" drill string at 29'.
9:20	Set 21' of 8" casing in hole - casing cannot be pushed further than 16'6" with head. Cut off 3'7" of steel casing, leave 11" s/u 8" casing.
9:40	Clean out hole to 29'.
9:45	Restart open hole drilling 8"Ø.
11:15	Drilled to 69' - basalt to 40'; damp/moist, orange/brown silty sand at 40 to 42'; basalt at 42 to 47'; moist red/brown clay at 47 to 49'; basalt at 49 to 67'; cinders at 67 to 68'; and basalt at 68 to 69'. Hit water at 65', water red/brown at 67' making 10 to 15 gpm. Analyzed for fluoride = 2.9 mg/l (Monsanto laboratory).
11:15 - 11:30	Pulled out 8" drill string.
11:30 - 12:30	Logged hole using Monsanto equipment - natural gamma, resistivity, and S.P.
12:30 - 1:15	Lunch.
1:15 - 3:15	Set 5' 20 slot PVC screen at 69 to 64', gravel packed with 12x2 gal pail gravel to 62.1 to 59.2'. 1x5' PVC screen + 3x20' blank PVC + 1x10' blank PVC. Centralizers at 44' and 10'. 3' s/u.
5:00	Grouted to within 3' surface with 1 yd 9 bag grout from Parsons - poured into dry hole.

WELL DEVELOPMENT - TW30

TW30 was developed on the morning prior to sampling (November 14th, 1984). The well was developed using a bailer. Forty gallons (about 6 well volumes) were evacuated from the well in the morning before the well was sampled in the afternoon. No measurements were made on the chemical quality of the bailed water. No water measurements were made following bailing.

TW 31

i) Schematic Test Well Completion

ii) Field Borehole Log

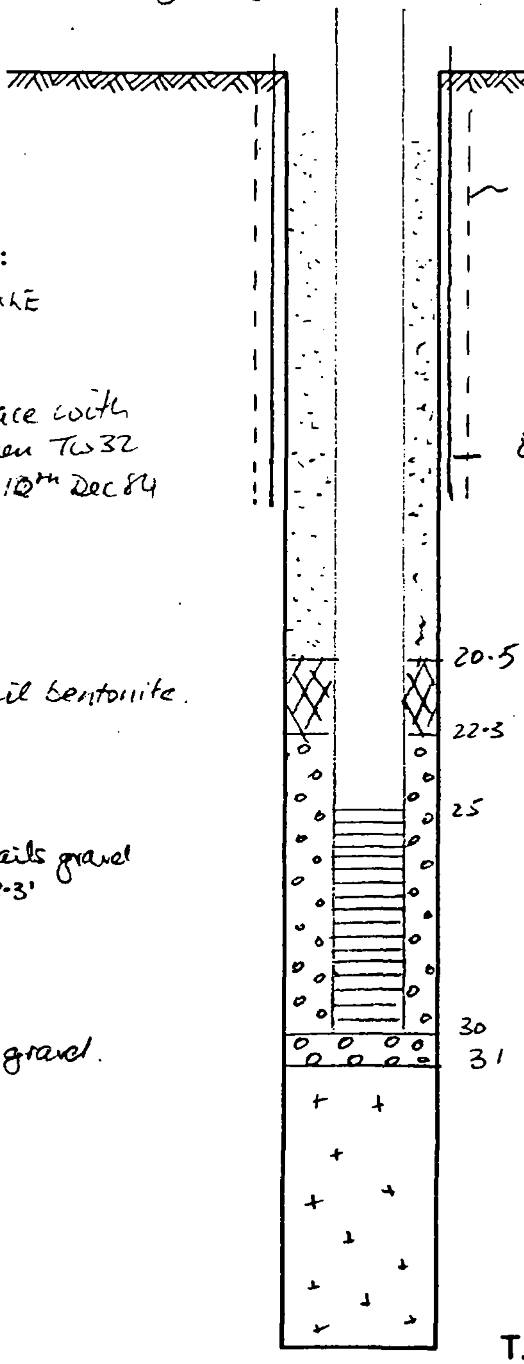
iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW 31

HOLE DIAMETER 10" 0-16'
8" 16-41'



10"ϕ open hole to 16'

REMARKS:
NOT TO SCALE

Grouted to surface with a 40 gals grout when TW32 was grouted on 10th Dec 84

8" casing to 16' (s/u = 6")

1x 50lb pail bentonite.

81x 2gal pails gravel to 22.3'

1x 5' 20 slot PVC screen
+ 1x20'
+ 1x10' } Blank PVC.

2 pails gravel.

T.D. = 42'

1 pail gravel = 2 gals.

PROJECT DRAWN REVIEWED DATE

Golder Associates

HYDROGEOLOGIC LOG

DRILLHOLE No. TW31
Sheet 1 of 1

Job No.

Project: MANGAWITO GROUNDWATER STUDY

Type of drilling: ROTARY

Rig: SCHRAMM T-64

Drilling fluid: AIR/WATER

Coordinates: E .... N ....

Angle from horizontal: 90°

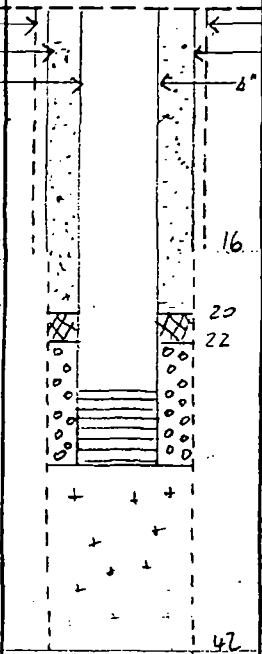
Bearing: / °Azimuth

Reference elevation: ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole: ....

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	During Drilling (2)(4) Water Level ~~(m)~~	During Drilling (5) Water Flow ~~(l/s)~~	During Drilling (6) ~~Other~~ Pen Rate	After Drilling (2)(7) Water Level ~~(m)~~	After Drilling Permeability (8) (2) Depth (m)	After Drilling Permeability (8) Method	After Drilling Permeability (8) Value (cm/s)	Comments
Ground Surface		ft	ft	gpm		T°C	Cond.	pH		
Brown silty SAND and GRAVEL	10" 8" 4"									
10										
Fresh grey BASALT 15.5 16.5	16									
Brown CLAY 19.5										
20	20 22									
Fresh grey BASALT 25		25	-	10		6	500	6.89		Drill bit falls at 25ft
30 SAND and GRAVEL										Caving in sand and gravel
40 41		41	20.5	10-20						
Fresh grey BASALT 42	42									
End of Borehole										



Contractor: Andrew Well Drilling
Date started: 3rd Dec 1984
Date finished: 3rd Dec 1984
Logged by: DB/MS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale: /

HISTORY OF HOLE

TW31

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/03/84

9:30 - 11:10	Move equipment to drill site, set up, start rig and allow to warm up (rig has been idle for 2 to 3 weeks).
11:10	Start drilling 8"Ø open hole. Bedrock at 15.5'.
11:40	Loose return at 19.5'. Try to set 8" casing to 19' - can not push casing past 3'.
12:00 - 1:00	Lunch.
1:00 - 1:25	Pull out 8" casing. Run 10"Ø bit to 16/17'.
1:25 - 1:35	Set 8" casing to 16' below ground - waste pipe = 2'6". s/u = 6".
1:35 - 1:40	Run 8"Ø drill stem, restart drilling.
2:00	Hit water at 25' - bit falls through a fracture?/void. Down 15 mins while 900 compressor is started.
2:15	Making 10 to 20 gpm from brown sand to sandy gravel at 25 to 41'. Water T = 6°C; C = 500 μmhos/cm; pH = 6.89. Hole is caving in gravel. Pull back drill string to 28' - hole caves to 29'.
2:35	Redrilled hole to 35' appears open, pull out drill string. Sounded hole to 31.5' below 2.6' s/u, therefore the depth = 28.9'. Water level = 20.5' below ground.
2:45 - 3:50	Log hole for natural gamma and resistivity.
3:50 - 6:10	Set 1x5' PVC 20 slot screen - threads teflon wrapped, centralizer at 20' below ground level, + 1x20' PVC blank + 1x10' PVC blank. Screen falls to 31' when set, therefore pulled out and 2 pails gravel added. Screen sets firmly at 30' below ground level. Gravel packed with 81x2 gal pails gravel to 22.3'. Bentonite seal with 1x50 lb pail to 20.5'.

DATE: 12/10/84

Grouted to surface with approximately 40 gals grout from the batch used in TW32.

WELL DEVELOPMENT - TW31

TW31 was developed on December 13th, 1984. One inch diameter tremie pipe was set to a depth of 27 ft and the well airlifted at about 1/2 to 1 gpm for 1 hour. The water initially contained a large proportion of brown fine sand, but cleared up after 10 mins of airlifting.

Chemical parameters of the airlifted water were measured during development. Stevens water level recorders monitored the response of TW32 and TW33:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH
20	1	275	8.87*
35	1	350	8.73
45	3	375	8.76
60	2	375	8.84

*Extreme Cold Affecting Instruments

F = 0.48 mg/1

The water level in TW33 drew down 0.05 ft during the development of TW31 (see Chart 1 TW33). The water level in TW32 drew down 0.02 ft during the same period.

TW 32

i) Schematic Test Well Completion

ii) Field Borehole Log

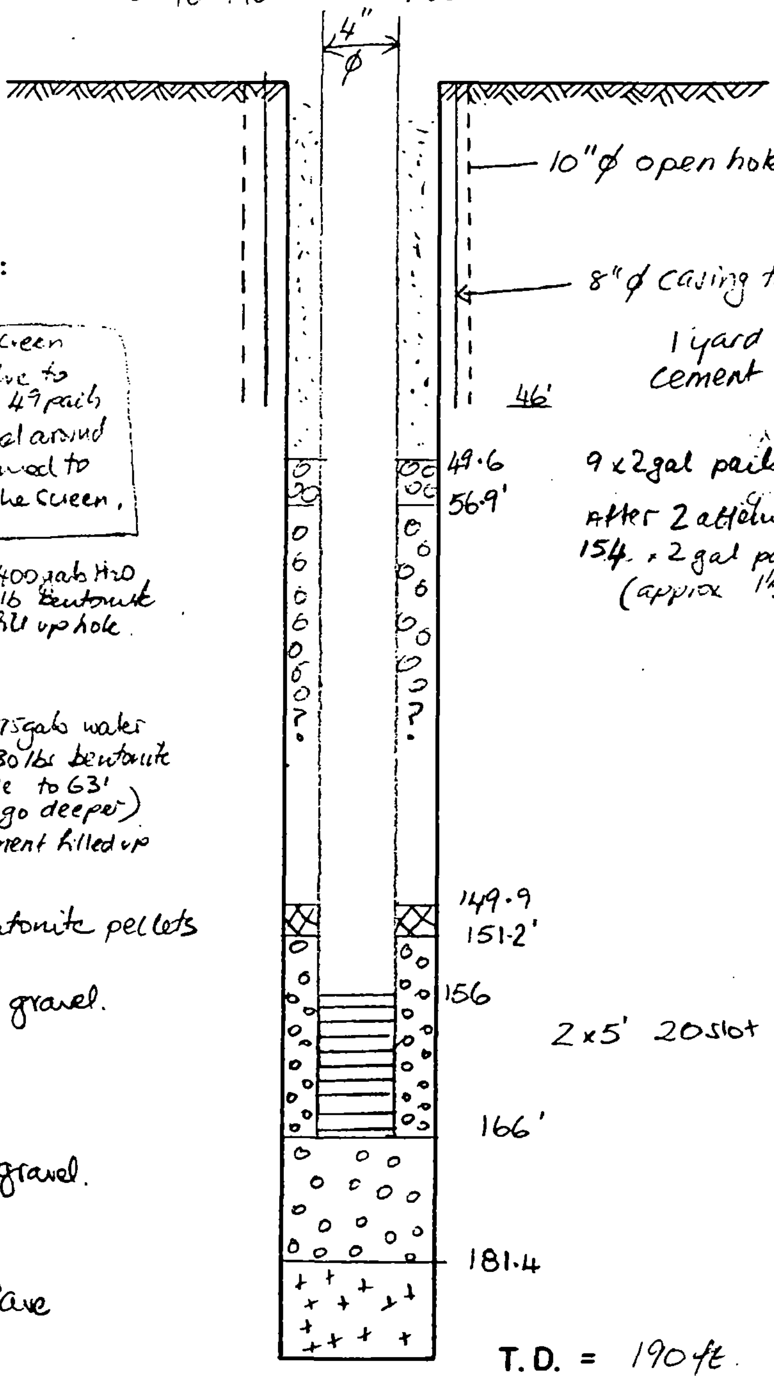
iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW32

HOLE DIAMETER 10" 0-46'
8" 46-190'



REMARKS:

NOT TO SCALE

Although hole "open" to 180', screen would only go down to 166' due to blockage in hole. The first 49 pails of gravel did not raise the level around the screen. This gravel is assumed to have filled up the hole below the screen.

Pumped 73 bags cement + 400 gals H_2O + 12lbs flocele + 30lb bentonite from 60' did not fill up hole.

Pumped 50 bags cement + 275gals water + 12½lbs flocele + 30lbs bentonite powder via tremie to 63' (tremie would not go deeper)
Not known how far cement filled up hole < 63' tho?

3 x 50lb pails bentonite pellets

63 x 2gal pails gravel.

49 x 2gal pails gravel.

Cave

T.D. = 190 ft.

DRAWN .... REVIEWED .... DATE .... PROJECT

HYDROGEOLOGIC LOG

DRILLHOLE No. TW22
Sheet 1 of 3

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: Air / Water

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation: ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~	During Drilling: (2) (4) Water Level ~~(m)~~	During Drilling: (5) Water Flow ~~(l/s)~~	During Drilling: (6) ~~Other~~ Pen Rate	After Drilling: (2) (7) ~~Water Level (m)~~	After Drilling: ~~Permeability~~ (2) Depth (m)	After Drilling: ~~Permeability~~ Method	After Drilling: ~~Permeability~~ (8) Value (cm/s)	Comments
Ground Surface		ft	ft	gpm	min/ft	T°C	C µS/cm	pH	—	
Brown silty SAND 5	10", 8", 4"									
Fresh grey BASALT 10										
Brown silty SAND AND GRAVEL 13										
Fresh grey BASALT 15										
Silty SAND and GRAVEL 16										
Fresh grey BASALT 20					5					
Silty SAND and GRAVEL and fractured faintly weathered BASALT 27					0.5					
					2					
Fresh grey BASALT					4.5					
					3.5					
					5					
	+6	47		5-10	6					
	49					5	600	7.11		
					3	5	600	—		
61					2.5	5	600	7.27		
Faintly weathered red/brown vesicular BASALT and CINDERS	63				1.5	7	600	7.27		
71					2					
Fresh grey BASALT 77					1.5	6	600	7.43		
Red/brown vesicular CINDERS 79					1.5	6	600	7.50		
Fresh grey BASALT					3	6	600	7.54		
					5.5					

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling
Date started: Dec. 4th 1984
Date finished: ....
Logged by: DB/MS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale: —

HYDROGEOLOGIC LOG

DRILLHOLE No. TW 32
Sheet 2 of 3

Project ....

Type of drilling .... Coordinates: E .... N ....

Rig ....

Drilling fluid .... Angle from horizontal ....

Bearing .... °Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

(1) (2)* Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) Other Pen Rate min/ft	After Drilling: (2)(7) Water Level ~~(m)~~ T°C	Permeability (8): (2) Depth (m) Cμ/cm	Method pH	Value (cm/s)	Comments
Contd										
90–97 Fresh grey BASALT					5.5, 2	5	600	7.52		Extreme cold prohibits continuous use of instruments
97–100 Brown silty SAND and CLAY					2.5					
100–110 Fresh grey BASALT					3.5, 3	6	625	7.45		
110–118 Fractured BASALT and brown SAND					2	3.5	625	7.40		
120 (118–131) Fresh grey BASALT					2.5, 2.5, 6.0	5	600	7.48		
130 (131–136) Red/brown CLAY					1.5					
140 (136–146) Fresh grey BASALT					2, 2.5	6	625	7.22		
146–150 Fractured BASALT with sand?	150				/					
150–161 Fresh grey BASALT	151				2.5, 3	7.5	625	7.45		
160 (161–165) Red/brown CINDERS with sand?					2					
165–168 Fractured BASALT with sand?	166									
170 (168–180) Red/brown CINDERS with some sand and clay	178				/, 1, 2	7	600	7.23		
180										

Contractor: .... Logged by: ....

Date started: .... Checked by: ....

Date finished: .... Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW 22
Sheet 3 of 3

Project ....

Type of drilling ....

Rig ....

Drilling fluid ....

Coordinates: E ....

N ....

Angle from horizontal ....

Bearing .... °Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2)(4) Water Level ~~(m)~~	(5) Water Flow ~~(l/s)~~	(6) ~~Other~~ Pen Rate	After Drilling (2)(7) Water ~~Level (m)~~	Permeability (8) ~~(2) Depth (m)~~	Method	~~Value (cm/s)~~	Comments
130 contin		ft	ft	gpm	min/ft	T°C	Cond/cm	pH		
Fractured BASALT with sand? 190	190				2 3	6	575	7.18		
End of borehole										

Contractor: ....
Date started: ....
Date finished: ....

Logged by: ....
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW32

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/04/84

7:30 - 8:50	Trying to start rig, pick up parts for primer pump on 900 compressor.
8:50 - 11:10	Drilling 10"Ø 0 to 46' - basalt at 5' - making water at 26', some sand in samples - pull out 10" bit and guide.
11:10 - 11:55	Set 8" casing to 46' - s/u = 6".
11:55 - 12:55	Lunch.
12:55 - 5:30	Drilling 8"Ø open hole 46 to 149'. Hole making 5 to 10 gpm at 45'. Hit cinder/vesicular loose zone at 66-1/2', red/brown water 20 gpm. Mixture of cinders and fresh basalt to 79'. Clay at 96-1/2 to 98'. Hole starts to make a lot of fine brown sand. Water is continually brown - hole makes increasing more water, about 100 gpm, and caves. Clay layer encountered at 132 to 135' and at 135 to 149' broken/fractured basalt? and sand. Decide to stop hole at 149' and log hole to compare with nearby holes.

DATE: 12/05/84

7:30 - 9:00	Trying to start rig.
9:00 - 9:40	Pull out 8" drill stem.
9:40 - 11:15	Log hole using natural gamma tool only.
11:15 - 11:40	Reset 8" drill stem to continue drilling.
11:40 - 12:40	Lunch.
12:40 - 12:55	Trying to start 900 compressor.
12:55 - 2:40	Drilled 8"Ø hole 149 to 190', hole making >100 gpm - water is dark brown and very sandy, some conglomerate fragments. Very fast drilling rate, hole is sloughing.
2:40 - 3:00	Pull out 8" guide and drill stem.
	Hole caves to 181.4'.

HISTORY OF HOLE

TW32

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/06/84

8:40 Washington State University geophysical logger arrives. Logs S.P., resistivity and caliper to 180'. Can not run natural gamma tool below 150', caliper tool may have disturbed hole since all tool are same size. Run natural gamma, neutron-neutron and gamma-gamma to 150'.

11:00 Finish logging.

DATE: 12/07/84

9:00 Move back over TW32. Sounded hole to 166.7' below 6" s/u, therefore hole is now open past blockage. Set up Monsanto logger and run natural gamma tool - tool cannot get past 150', feels like rock. Think hole shows deviation and long tool cannot get past kinks in hole.

10:10 - 11:10 Set 4"Ø PVC pipe and screen in hole. 2x5' 20 slot screens + 8x20' blank PVC + 1x10' blank PVC. Centralizers at 10', 50', 90' and 130'. PVC drops through obstruction at 150' to sit at 166'.

11:10 - 12:15 Trying to log through casing, can only get natural gamma tool to 163', although sounder can pass to 166'. Appears PVC is bent and tool cannot move around kinks in pipe.

1:00 - 5:00 Gravel pack well and place bentonite seal. Took 49x2 gal pails pea gravel to bring hole up to bottom of screen. Appears gravel probably falling below 66' to at least 180' where hole initially caved to. 63x2 gal pails to gravel pack to 151.2' (caliper log shows hole diameter up to 12" in this location). 150 lbs bentonite pellets to 149.9' - calliper log indicated hole 8"Ø, therefore bentonite must be lodged in hole, although probe could always reach bottom.

HISTORY OF HOLE

TW32

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/08/84

7:45	Depth to water inside PVC = 8.49 m (27.85') and outside PVC = 8.13 m (26.67') - appears to be a seal in borehole.
7:50	Run 1"Ø tremie pipe, pipe stuck at 60' - feels soft. Attach air hose to tremie pipe and airlift hole - about 1/2 pail congealed bentonite blown to surface. However, still cannot ged past 60'.
8:40	Pull out 1" pipe and move over to TW33.
9:05	Depth to water inside and outside PVC - 8.395 m (27.54'), therefore may have removed blockage.
11:30	Move back onto TW32. Run tremie pipe to 60', hole blocked. Attach air hose to tremie pipe and evacuate open hole - water is cement grey (had just grouted TW33). Stop airlift-ing.
12:00 - 1:00	Lunch - talk with D. Goldman, decide all we can do is grout up hole.
1:00 - 2:20	Wait for Parsons cement truck - brings 50 bags cement in 275 gals water. Add 12-1/2 lbs Flocele + 30 lbs bentoniote pow-der, mix for 20 mins. (Enough cement for about 120' of 8" hole with 4" PVC inside.)
2:45 - 3:05	Pump cement into TW32.
3:05 - 3:25	Clean out cement pump and tremie pipe. Run sounder - cannot feel any cement to 60'.
	TW33 depth to water = 8.90 m (29.20') below top of PVC.

DATE: 12/09/84

12:00	Depth to water = 7.96 m (26.11') inside PVC. = 7.86 m (25.78') outside PVC.
	Cannot feel any grout to 63'.

HISTORY OF HOLE

TW32

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/10/84

8:35	Depth to water inside PVC = 7.855 m (25.77'); and 7.81 m (25.62') outside PVC. Run sounder - cannot get past 19.2 m (62.72') - this is same as where hole caved.
9:00	Run tremie pipe to 60'.
9:00 - 9:30	Wait for cement truck to arrive.
9:30	Cement truck arrives with 73 bags cement, 400 gals water - add 30 lbs bentonite powder and 12-1/2 lbs Flocele, mix for 15 mins.
9:45	Use 40 gals of grout to top up TW31, and 60 gals to top up TW33. Pump remainder into annulus of TW32.
11:00	Finish pumping cement.
11:00 - 11:30	Clean up equipment, rinse out cement pump and tremie pipe.

DATE: 12/13/84

Added 154x2 gal pails gravel to bring level up to 56.9', then added 9x2 gal pails to 49.6' and 1/2 yd 9 bag grout to fill to surface.

WELL DEVELOPMENT - TW32

TW32 was developed on December 12th, 1984. One inch diameter tremie pipe was initially set to 60 ft, but following 30 mins of airlifting reset to 100 ft. The well was airlifted at a rate of about 2 gpm and remained relatively clear during development. Chemical measurements of the discharge water were taken during development and Stevens water level recorders monitored water levels in TW31 and TW33 during development.

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH
15	-1	475	7.68
30	-0.5	450	7.73 Tremie set deeper
40	0	1500	10.35*
55	3	3100	10.49*
60	4	2525	10.8*

*Equipment may have malfunctioned due to extreme cold.

F = 0.30 mg/1

The water level in TW31 did not respond to developing TW32. The Stevens water level recorder showed the water level in TW31 rising following the drawdown induced by developing TW33. The water level in TW33 drew down about 0.40 ft during the development of TW32 (see Chart 1 TW33).

TW 33

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

HYDROGEOLOGIC LOG

DRILLHOLE No. TW33
Sheet 1 of 1

Job No.

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E ....
N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation: ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~	During Drilling: (2)(4) Water Level ~~(m)~~	During Drilling: (5) Water Flow ~~(L/s)~~	During Drilling: (6) ~~Other~~ Pen Rate	After Drilling: (2)(7) Water ~~Level (m)~~	Permeability (8): (2) Depth (m)	Permeability (8): ~~Method~~	Permeability (8): ~~Value~~ (cm/s)	Comments
Ground Surface		ft	ft	gpm	min/ft	T°C	Cask	pH	—	
Brown sandy SILT 2	10"									
Fresh grey vesicular BASALT 7	8"; 4"									
Brown CLAY 8										
10 Fresh grey BASALT					3.5					
					6.0					
20										damp at 22'
Fresh grey fractured BASALT, trace clay 27		25		1	1.0					
30 Fresh grey BASALT					4.0					
	35				3.0					
40					1.0					
49					5.0					
50 Fractured BASALT and SAND 51					7.0					
Fresh grey BASALT 60					4.0					
					1.5					
60 Faintly weathered red/brown vesicular BASALT 62										
Fresh grey BASALT 67	65; 67				1.5					
Faintly/slightly weathered red/brown vesicular BASALT and CINDERS 75 (70)	74	75	25	20-30	1.0	6	575	7.41		
					1.0					
End of Borehole										
80										

Contractor: Andrew Well Drilling
Date started: 5th Dec. 1984
Date finished: 8th Dec. 1984
Logged by: DB/MS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

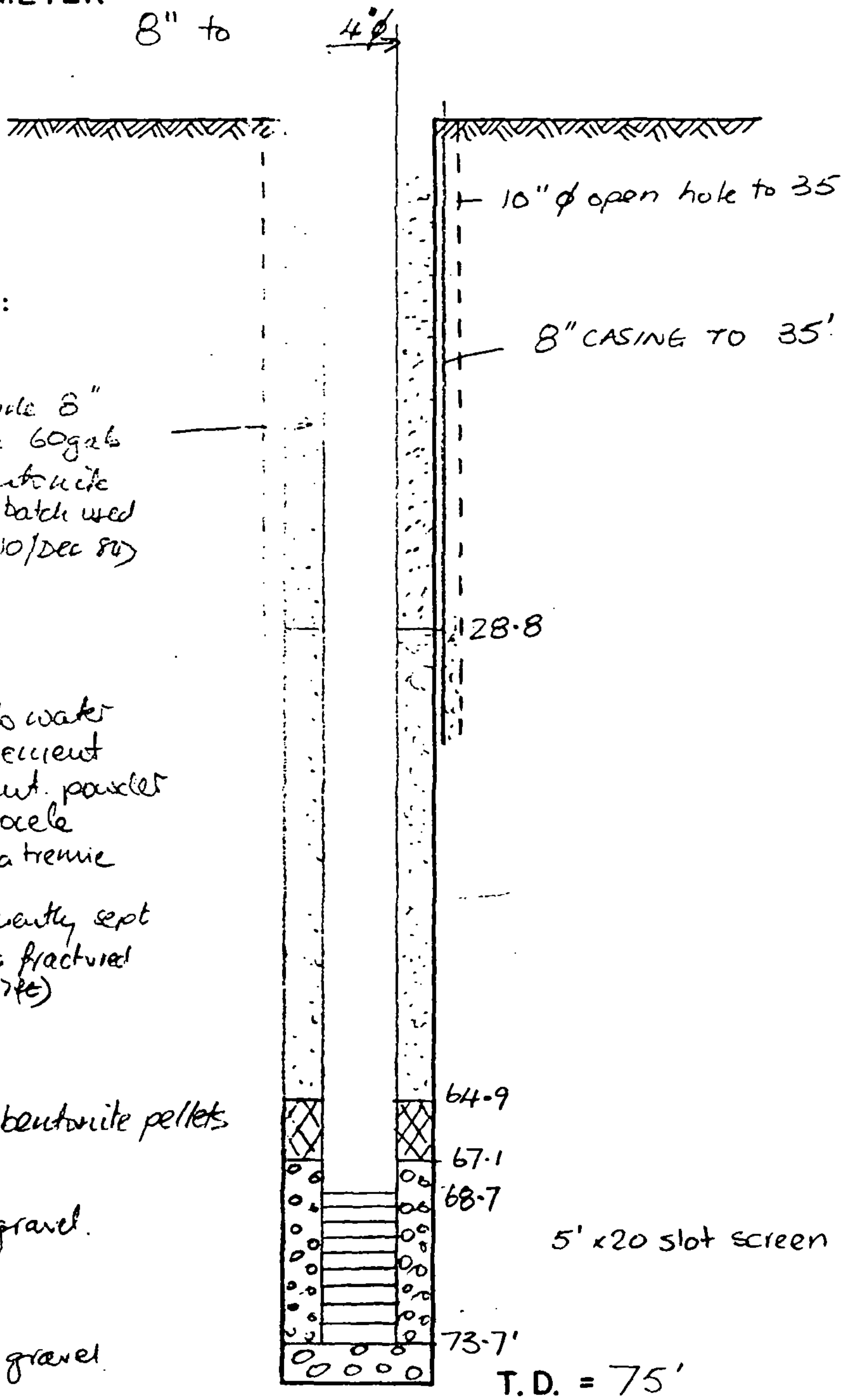
Scale: —

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW33

HOLE DIAMETER 10" to
8" to



REMARKS:
NOT TO SCALE.

Grouted inside 8" casing with approx 60gals cement with bentonite and flocele (from batch used for TW32 on 10/Dec 80)

Grout: 400gals water
73 bags cement
30lbs bent. powder
12½lbs flocele
pumped via tremie to 60'
(Much of grout apparently sept out of hole prob via fractured zone between 20-27ft)

1 x 50lb pail bentonite pellets

8 x 2gal pail gravel.

1 x 2gal pail gravel

PROJECT DRAWN REVIEWED DATE

Golder Associates

HISTORY OF HOLE

TW33

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/05/84

p.m. 3:30	Move and set up on TW33. Drilling 8"Ø open hole.
3:35	Drilling to 7', pull out 8" bit, run 10"Ø bit and ream out.
3:45	Drilling 10"Ø from 7'. Bedrock at 2', damp at 22 ft - making 1 gpm at 25' from gravelly clayey zone.
4:50	Drilled to 27'.

DATE: 12/06/84

7:30 - 8:30	Drillers try to start rig (extremely cold). Unable to start 900 compressor.
8:30 - 8:55	Allow rig to warm up.
8:55 - 9:25	Drilled 10"Ø open hole to 35' - very little return due to large hole and lack of additional compressor.
9:25 - 10:50	Pull out 10" bit and guide, set 8" casing. Total length 37.5', s/u about 2.5'.
10:50 - 11:00	Wait while WSU finishes logging adjacent hole.
11:00 - 11:45	Drilling 8"Ø 35 to 49'.
11:45 - 12:30	Lunch.
12:30 - 1:55	Drilled 8"Ø to 75', hit cinder zone at 69' - increase in water production.
1:55 - 2:05	Pulling out 8" bit and drill stems, depth to water 8.49 m (27.85'), -2.5' s/u = 25' below ground surface.
2:05 - 3:05	Logging hole with Monsanto equipment - natural gamma, resistivity and S.P.
3:05 - 5:30	Set 1x5' PVC 20 slot screen on bottom (73.7'); 8x2 gal pails gravel to gravel pack well to 67.1 ft; 1x50 lb pail bentonite pellets to 64.9'. Following installations, depth to water below top of PVC = 8.55 m (28.05'); depth to water outside PVC in casing = 8.55 m (28.05').

HISTORY OF HOLE

TW33

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/07/84

a.m. 9:05	Depth to water in PVC = 8.535 m (28.00'); depth to water outside PVC = 8.56 m (28.08'), therefore upward head?

DATE: 12/08/84

8:55	Move and set up over hole. Run 1"Ø tremie pipe to 60'. Depth to water 8.34 m (27.36') inside and outside PVC - different from December 7th.
9:30	Parsons cement truck arrives. 73 bags cement and 400 gals water. Added 1/2 bag (12-1/2 lbs) Flocele + 30 lbs bentonite powder. Mixed for 15 mins.
9:50 - 10:20	Cement pump frozen - thaw pipe.
10:20 - 11:30	Pump cement into hole - water seen cascading over steel casing as cement displaces water. However, hole takes all cement even though the quantity is 2 times volume required.
11:30	Move rig off. Cement feels about 12 m (39.4') below ground level. Think much of cement moved up outside 8" steel casing into overlying fractured zone.
12:50	Depth to water inside PVC = 8.36 m (27.42') / outside PVC = 8.32 m (27.29'); same datum.
3:50	Depth to water 8.25 m (27.06') inside PVC.

DATE: 12/09/84

12:00	Depth to water inside PVC = 7.815 m (25.64') / outside PVC = 8.41 m (27.59'). Depth of grout = 9.9 m (32.48') below top of steel casing (2' s/u) and 30.5' below ground.

HISTORY OF HOLE

TW33

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/10/84

9:00 Sounded grout to 9.4 m (30.84') below top of steel casing (2' s/u) = 28.8' below ground level. Depth to water = 7.77 m (25.49'). Added approximately 60 gals grout to annulus of well when TW32 was grouted. Grout about 2' below surface when completed. Cut 8" steel casing to ground level.

WELL DEVELOPMENT - TW33

TW33 was developed on December 12th, 1984. One inch diameter tremie pipe was set to a depth of 60 ft and the well airlifted at a rate of 10 gpm for about 1 hour. The water was stained slightly brown at the start of development, but cleared up. Chemical parameters of the discharge water were measured during development and Stevens recorders monitored the effect of development on TW32 and TW31.

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH	Eh (Mv)
8	8	300	8.78	-29
20	7.5	490	7.8	+20
35	7	525	7.65	67
48	6.5	525	7.68	131
60	6	525	7.67	101

F = 0.275 mg/1

The water level in TW31 drew down 0.17 ft during the development of TW33 (see Stevens chart for TW31 - Chart 1). The water level in TW32 apparently drew down about 4 ft during the same period; however, the Stevens recorder did not appear to be working well at the time.

TW 34

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

~~PIEZOMETER~~ WELL INSTALLATION DATA

Figure

BOREHOLE TW 34

HOLE DIAMETER 10" 0-47'
8" 47-74'

REMARKS:

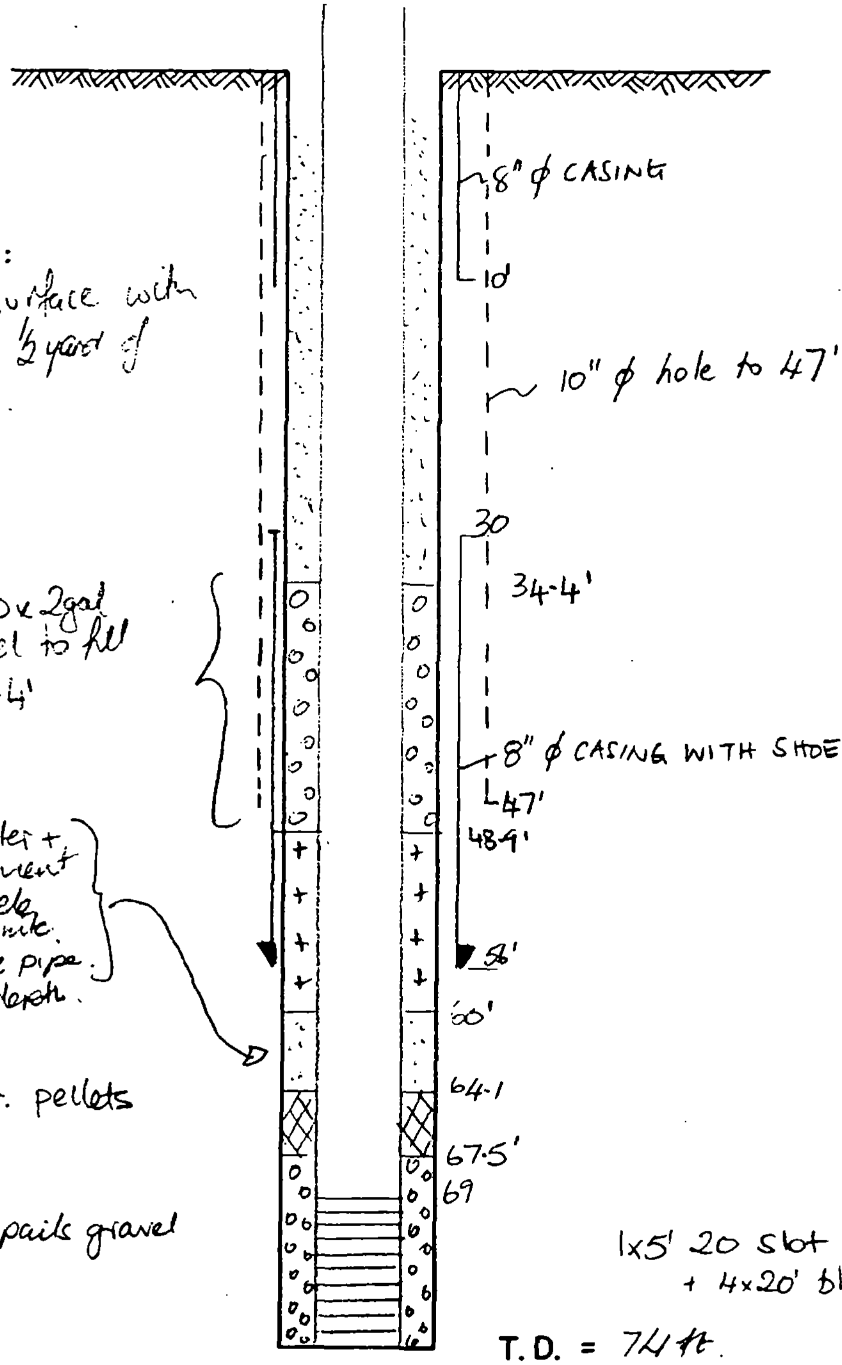
Cemented to surface with approximately ½ yard of 9 bag grout.

Added 120 x 2gal pails gravel to fill hole to 34.4'

Pumped 275 gals water + 50 bags cement + 12½ lbs flocele + 30 lbs bentonite into hole via tremie pipe. Approx sounded depth.

100 lbs bent. pellets

6½ x 2gal pails gravel



1x5' 20 slot PVC Screen + 4x20' blank PVC pipe.

T.D. = 74 ft.

DRAWN .... REVIEWED .... DATE ....

PROJECT ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW34
Sheet 1 of 1

Project: MONSANTO GROUNDWATER STUDY

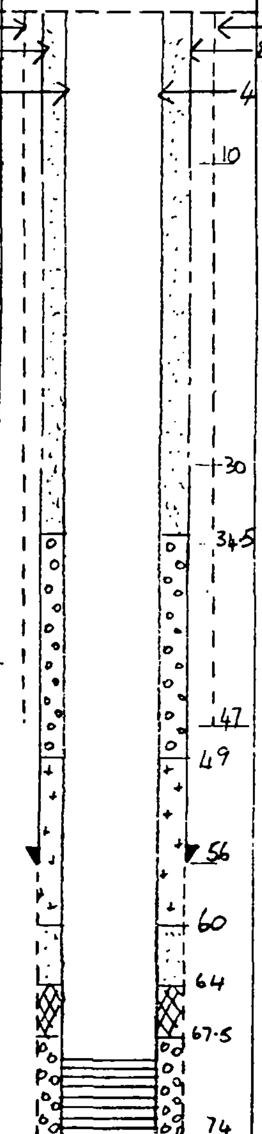
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation: ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2)* Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) ~~Other~~ Pen Rate min/ft	After Drilling: (2)(7) Water Level ~~(m)~~ T°C	~~Permeability (8)~~ (2) Depth (m) C µ/cm	Method pH	Value (cm/s)	Comments
Ground Surface										
0–3 Brown silty CLAY	10"									
3–4 Faintly weathered BASALT	8"									
4–8 Brown silty CLAY	4"									
8–10 Fractured sl. weathered BASALT	10									
10–39 Fresh grey BASALT (20, 30)	30, 34.5				8, 11, 11, 12, 12, 12					Damp at 27'; 8" casing cut at 30' and pulled back to 10' below ground level.
39–41 Faintly weathered BASALT (40)				50-60		6	775	7.30		Depth (ft) 41.5, F (mg/l) 1.88
41–43 Fresh grey BASALT										
43–66 red/brown to grey loose scoriaceous CINDERS and vesicular BASALT (50, 60)	47, 49, 56, 60, 64			100-200	3, /, /, /, 2	6	825	7.38		46 — 3.6; 47 — 3.4
66–67 Fresh grey BASALT	67.5									
67–71 Red/brown scoriaceous CINDERS and brown CLAY (70)					3					68 — 39
71–74 Fresh grey BASALT	74			100-200	5					74 — 40
End of Borehole (80)										



Contractor: Andrew Well Drilling
Date started: 10th Dec 1984
Date finished: 12th Dec 1984

Logged by: DB/MS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW34

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/10/84

11:30 - 12:00 and 12:45 - 1:00	Move and set up over hole.
1:00	Start drilling 10"Ø open hole. Encountered silty clay at 0 to 3', basalt at 3 to 4', silty clay at 4 to 8', weathered basalt at 8 to 10', and fresh grey basalt - very strong - at 10 to 35'. Drilling progress very slow due to extremely strong rock - cuttings damp at 25' and some water at 27'.
6:00	Finish drilling at 35'.

DATE: 12/11/84

7:50	Started drilling from 35' 10"Ø - entered cinder zone at 43', loose, scouriaceous, making in excess of 100 gpm, probably 200 to 300 gpm.
9:10	Drilled to 47' still in cinders, hole open to 46-1/2'.
9:15	Pulled out drill string.
9:25 - 11:45	Setting 8"Ø casing in hole. First of all set casing to 47' and continued drilling open hole, but cinders till at least 56'. Therefore, pulled drill string and added more casing. 21'4" + drive shoe + 21' + 6' + 13' = 61'4" total 8" casing, cutoff 2'6"; s/u = 2'.
11:45 - 1:00	Lunch.
1:00 - 2:00	Using downhole hammer to vibrate casing to approximately 56-1/2' - steel plate falls into hole plate = 2"x6"x1/4" - subsequently drilled out.
2:05	Started drilling open hole from 57', appears to be cindery/ vesicular basalt through to 66' - thin fresh basalt layer 1' thick. Another cinder zone/weathered basalt sequence 67 to 71'.
3:10	Becomes harder drilling at 71 to 74' (fresh basalt).

HISTORY OF HOLE

TW34

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/11/84 (Cont'd)

3:10 - 3:45 Wait for DB to run fluoride analyses on ground water samples - pull out drill stem at 3:10 - 3:30

Depth (ft)	Fluoride (mg/l)	Monsanto Analysis
41.5	1.88	
46	3.6	
47	3.4	3.55
68	3.9	3.9
74	4.0	3.85

3:45 - 4:30 Log hole using natural gamma and resistivity tools.

4:30 - 4:50 Drillers standby while DB calls Vancouver to discuss hole completion.

DATE: 12/12/84

7:30 - 8:15 Run casing cutter to 30', pressurize and rotate for approximately 15 to 20 mins.

8:15 - 9:55 Set 5' screen and 4x20' blank PVC pipe to bottom of hole. Screen = 74 to 69'. Gravel pack with 6-1/2x2 gal pails gravel at 73.9 to 67.5', and add 100 lbs bentonite pellets at 67.5 to 64.1'. Run 1"Ø tremie pipe to 60' and set up for grouting.

9:55 - 11:30 Wait for Parsons cement truck to come.

11:30 - 12:15 Truck arrives with 50 bags cement and 275 gals water. Add 12-1/2 lbs Flocele, 30 lbs bentonite and mix for 10 minutes. Pump grout into borehole annulus. After pumping, could not feel any grout in borehole.

12:15 - 12:30 Pull 1" tremie pipe and rinse out cement mixture.

12:30 - 1:20 Lunch. Sound grout (?) to approximately 19 m (62.3') - 2-1/2', therefore may have filled up about 4.5' of annulus with grouted.

1:20 - 2:30 Pull 8" casing, pull out 20'1" of 8" casing. This should leave approximately 10' of surface casing and casing between 30 and 50'. After casing pulled, hole sounded to 14.9 m (48.9'). Added 2 yds 9 bag grout, sounded to approximately 15 m (49.2'). Grout probably disappearing into cinder zone.

HISTORY OF HOLE

TW34

GEOLOGIST: D. Banton / M. Shaleen DATE: 12/13/84

Decided to fill up borehole to top of cinder zone with gravel then cement up to the surface. It is likely that since all the grout disappeared through a zone where supposedly casing should be, the casing, although cut, did not separate at 30. Instead, pulling back the casing 20' exposed the grout to the extremely permeable cinder zone. The grout thus sept away.

1:10 - 2:00 Back fill from 48.7' to 34.4' with 120x2 gal pails of pea gravel.

DATE: 12/14/84

Cemented to surface with approximately 1/2 yd 9 bag grout (sand/cement mixture).

WELL DEVELOPMENT - TW34

TW34 was developed on December 13th, 1984. One inch diameter tremie pipe was set to a depth of 60 ft and the well airlifted. Due to the slow recovery of the well, the air was turned off and the well allowed to partially recover before being evacuated for a second and third time. Chemical parameters from each slug of water were measured.

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH	F (mg/l)
2	6	675	8.64	3.8
15	6.5	650	9.05	2.4
30	6	600	8.55	1.35

No measurable drawdown was recorded in either TW19, TW20 or TW21 during development.

TW 35

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA

Figure

BOREHOLE TW35

HOLE DIAMETER 12" 0-25'
10" 25-57'
8" 57-128'

2/14/85 ½ yard 9 bag grout + 1 yard 8 bag grout } fills hole to surface

REMARKS:

NOT TO SCALE

GROUT

2/13/85 – 20 bags cement
120 gals. H_2O
15 lbs. bent
6 lbs. flocele
} to 45.9'

2/11/85 – 10 bags cement
55 gals H_2O
7-8 lbs bentonite
1 lb flocele
} to 53.4'

50 lbs bentonite pellets

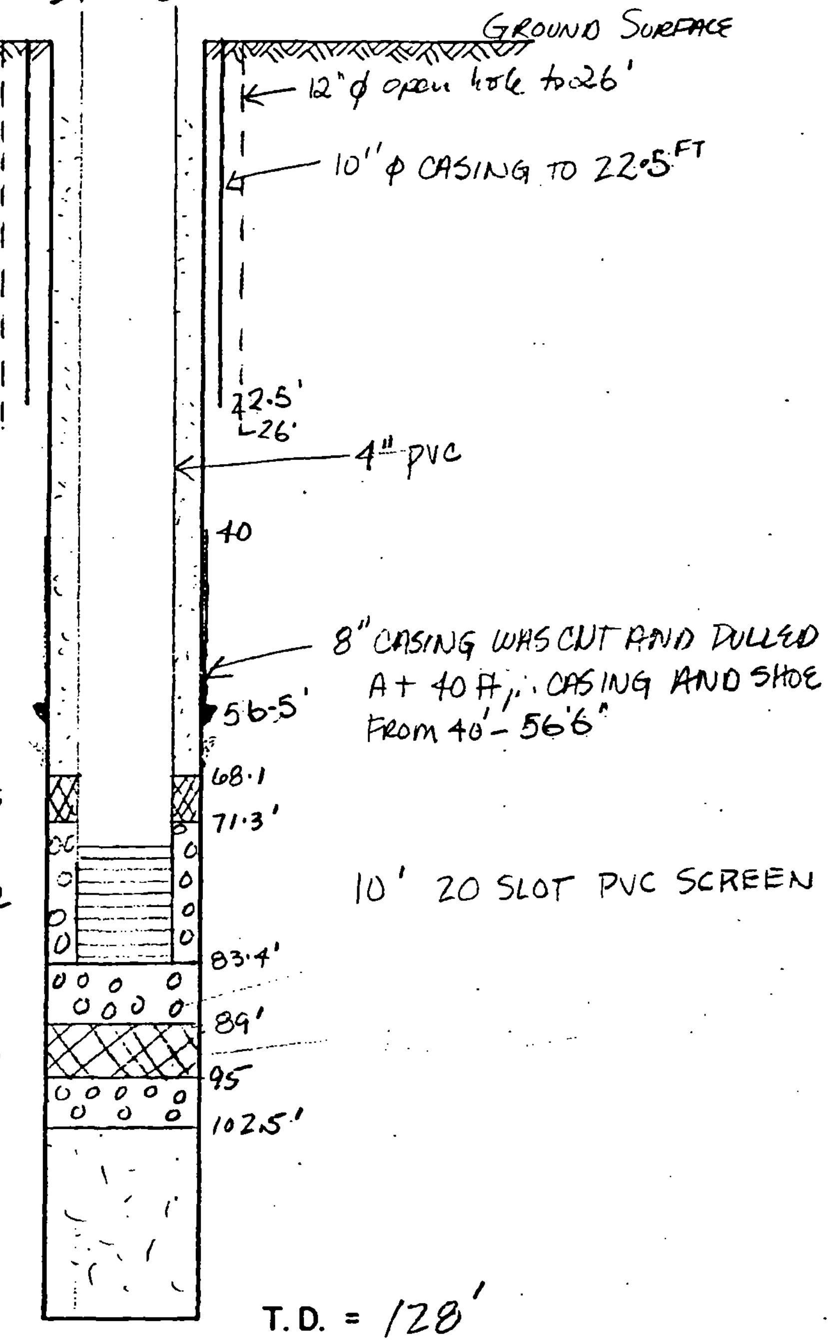
28 x gal pails pea gravel

23 x gal pails pea gravel

150 lbs. bentonite pellets

30 x gal pails pea gravel

Grout set with tremie
15 bags cement
82 gallons H_2O
20 lbs bent
1-2 lbs. flocele



T.D. = 128'

PROJECT NO. .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW35
Sheet 1 of 2

Job No.

Project: MONSANTO GROUNDWATER STUDY

Type of drilling: ROTARY

Rig: SCHRAMM T-64

Drilling fluid: AIR / WATER

Coordinates: E .... N ....

Angle from horizontal: 90°

Bearing: — °Azimuth

Reference elevation: ....

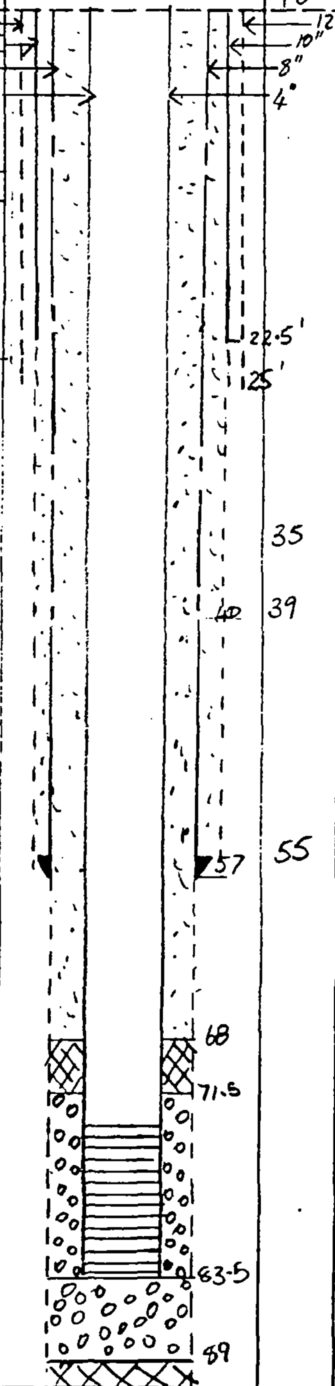
Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole: MONITORING WELL

(1) (2) * Lithology	During Drilling (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) ~~Other~~ Pen. Rate min/ft	After Drilling (2)(7) Water Level ~~(m)~~ T°C	Permeability (8) (2) Depth (m) Cond/ls	Method pH	Value (cm/s) F (mg/l)	Comments
Ground Surface									
Brown silty CLAY 1.5				1.5					
Fresh grey BASALT 2.5									
Black sl. to mod. weathered BASALT 10.5				2.6					
Fresh grey BASALT 12.5				2.0					
Brown black, sl. to mod. weathered BASALT occ sandy. 23				1.2					
				2.8					
Fresh grey BASALT 50				5.0					
	35		5	7.0	15	1250	7.5	11.1	
	39	20.7		7.0					CUT 8" STEEL CASING AT 40' PULLED OUT 0-40' CASING.
				9.4					
				8.6					
Red/brown base Scoriacious CINDERS 57			>100	2.0	8	1000	6.72	10.8	CASED OFF CINDER ZONE BEFORE DRILLING DEEPER.
	55	25.5			12	990	6.72	10.9	
Fresh grey BASALT 75				5.0					
				5.0					
			1-2	4.2	5	1200	8.19		
Red/brown silty SAND and CINDERS 78				4.0					
Fresh grey BASALT				2.0					
			5	3.0	5.5	890	7.21	.48	
				4.4					

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

(2) (3) Completed Construction



Contractor: Andrew Well Drilling
Logged by: DB / KES
Date started: 28th Jan 1985
Checked by: ....
Date finished: 14th Feb 1985
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW35
Sheet 2 of 2

Project ....
Type of drilling ....
Rig ....
Drilling fluid ....

Coordinates: E ....
N ....
Angle from horizontal ....
Bearing .... °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole ....

Job No.

(1) (2)* Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~	During Drilling: (2)(4) Water Level ~~(m)~~	During Drilling: (5) Water Flow ~~(l/s)~~	During Drilling: (6) ~~Other~~ Pen Rate	After Drilling: (2)(7) Water Level (m)	After Drilling: Permeability (8): (2) Depth (m)	After Drilling: Permeability (8): Method	After Drilling: Permeability (8): Value (cm/s)	Comments
Contd		ft	ft	gpm	min/ft	T°C	C µS	pH	F (mg/L)	
	8"				4.4	5	1075	7.19		
Fresh grey	95				3.2					
100 BASALT	102.5				4.4	5	1100	7.23		
					5.0					
110					6.0	7	1000	7.33		
					4.0					
120					5.0					
123									.45	
CLAY 125				20	1.5					
Fractured, fresh grey BASALT 128	128									
End of Borehole										
130										

Contractor ....
Date started ....
Date finished ....

Logged by ....
Checked by ....
Date ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW35

GEOLOGIST: D. Banton / M. Shaleen DATE: 01/28/85

3:05	Started drilling 10"Ø open hole. Encountered overburden at 0 to 1', basalt at 1 to 1.5', overburden or weathered basalt at 2.5 to 5', weathered basalt at 5 to 12.5', sandy silt, weathered basalt, brown/black at 12.5 to 23', and fresh grey basalt at 23 to 35'.
5:45	Stopped drilling at 37-1/2'. Becomes damp at 32', makes water at 35' - about 5 gpm. F = 11.1 mg/l.

DATE: 01/29/85

7:50	Restart drilling from 37.5' @ 10"Ø open hole. Hole starts to cave at 39' - probably from loose material between 12 to 23' is washed out by water.
8:30	Pulled out rods. Depth to water = 6.3 m (20.67') below ground; hole caved to 7.5 m (24.5').
8:30 - 10:00	Drillers go to fill up fuel truck, collect new bit.
10:00 - 11:00	Drillers pick up 10" casing from yard with help from Monsanto.
11:00 - 11:40	Change 12" bit on reaming tool.
11:40 - 12:10	Reaming 12"Ø 0 to 25/26'.
12:30 - 1:15	Lunch.
1:15 - 2:50	Set 24' of 10" casing, s/u about 1.5' therefore casing set to about 22.5'.
2:50	Drilling 10" open hole (cleaning out cave materials).
3:23	At 40' not much water due to cave in borehole.
3:53	50' change from fresh grey basalt to cinders - water flow increases from 5 gpm to 100 to 200 gpm. F at 50' = 10.8 mg/l; F at 55' = 10.9 mg/l.
5:10	Drilled to 56' still in cinders, pull out to set up hammer to drive 8" casing.
5:10 - 7:10	Set up hammer, weld on 8" drive shoe to casing.

HISTORY OF HOLE

TW35

GEOLOGIST: D. Banton / M. Shaleen DATE: 30/01/85

8:45	Welding 8"Ø casing, then set in TW35 - 59'3", of which 2'6" is s/u, set casing with downhole hammer, casing set to about 56'6".
11:30	Drillers picked up oxygen and acetylene tanks at supply truck.
11:50	Lunch.
12:40	Restart drilling 8" open hole at 56'. Change from cinders to fresh grey basalt about 56'6" - with water flow from well only 1/2 to 1 gpm.
5:50	Continued drilling 8"Ø open hole till 128/129'. at 76'6", water flow increased to about 5 gpm within sand and cinder interval. Changed back to basalt at 82' and continued till 124' (at 88 to 90' water flow increased to 10 gpm), 2' of clay, 126 to 128/129' changed back to basalt - water flow increased to about 20 gpm. Water samples - from 81' F = 0.48 mg/l; from 122' F = 0.45 mg/l.

DATE: 02/07/85

10:00	Moved back over TW35 preparing to grout up hole. Run 1"Ø tremie pipe to 125' below ground level.
11:25	Cement arrives - 15 bags x 5-1/2 gals water, added same bentonite powder and Flocele, mixed for 15 mins.
11:40 - 12:15	Pump grout into borehole.
12:15 - 12:45	Clean up equipment, pull out tremie pipe, move rig off hole and allow grout to set up.

HISTORY OF HOLE

TW35

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/11/85

10:00	Sounded depth to grout = 31.85 m below 2' s/u = 104.5' - 2' = 102.5' below ground.
10:00 - 11:25	Run casing cutter to 40', pressurize and rotate inside 8" steel casing. Steel casing "pops" up when cutter pulled out of hole.
11:25 - 12:05	Add 6x5 gal pails gravel to bring hole to 95', 3x50 lb pails bentonite pellets to 89' and 4.6x5 gal pails gravel to bring hole to 83.4'.
12:05 - 12:55	Lunch.
12:55 - 2:50	Set 2x5' 20 slot PVC screens at 83.4 to 73.4'; set 2x20 and 4x10' blank schedule 40 PVC to surface; use teflon tape on threads and centralizers. Gravel pack screen to 71.3' below ground with 5.6x5 gal pails gravel. Add 50 lbs bentonite pellets to 68.1'.
2:50	Try to pull 8" casing out of hole - pull about 3' and sound hole - hole open to bottom. Decide to leave 8" casing in hole till after grouting.
3:20	Order cement from Parsons. 60 bags with 330 gals water. Run tremie pipe to 60' for cement.
3:45	Cement truck arrives. Add 12-1/2 lbs Flocele + 1/2 bag bentonite powder, mix for 10 to 15 mins.
4:10	Started pumping cement. Approximately 5 mins pumping then cement pump cracked under pressure. Disassembled pump and pulled tremie pipe from borehole. Remaining cement taken to TW38.
5:00	Drillers left site.

HISTORY OF HOLE

TW35

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/13/85

p.m.

1:00 Order cement from Parsons - 50 bags and 300 gals water. Sound grout to 53.97' below ground surface. Depth to water inside 4" PVC = 8.605 m (28.23'); outside 4" PVC = 8.84 m (29.00'). Therefore, seems first load of grout sealed lower well from cinder zone.

2:00 Run 1"Ø tremie pipe to 40'.

2:05 Cement arrives, add 1/2 bag (12-1/2 lbs) Flocele + 30 lbs bentonite powder, mix for 15 mins.

2:25 Started pumping cement, pumped approximately 1/2 load in TW35. Cement should fill hole but probably being lost in cinder zone around casing cut.

3:15 Pull out remainder of 8" pipe, i.e. 40'.

3:20 Move off hole to TW39 to use rest of cement.

DATE: 02/14/85

Sounded grout to 14 m (45.9'). Added 1/2 yd 9 bag grout and sand, followed by 1 yd of 8 bag grout and sand mix to fill borehole to surface.

WELL DEVELOPMENT - TW35

TW35 was developed on January 14th, 1985. One inch diameter tremie pipe was set at a depth of 39 ft and the well airlifted at approximately 1 to 2 gpm for 1 hour. Chemical parameters of the airlifted water were measured during development. Stevens water level recorder monitored the response in TW39.

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH
10	6	1175	7.46
25	6.5	1250	7.49
40	7	1250	7.55
55	7.5	1300	7.55

F = 0.33 mg/1

No response was observed in TW39 during development of TW35.

TW 36

i) Schematic Test Well Completion

ii) Field Borehole Log

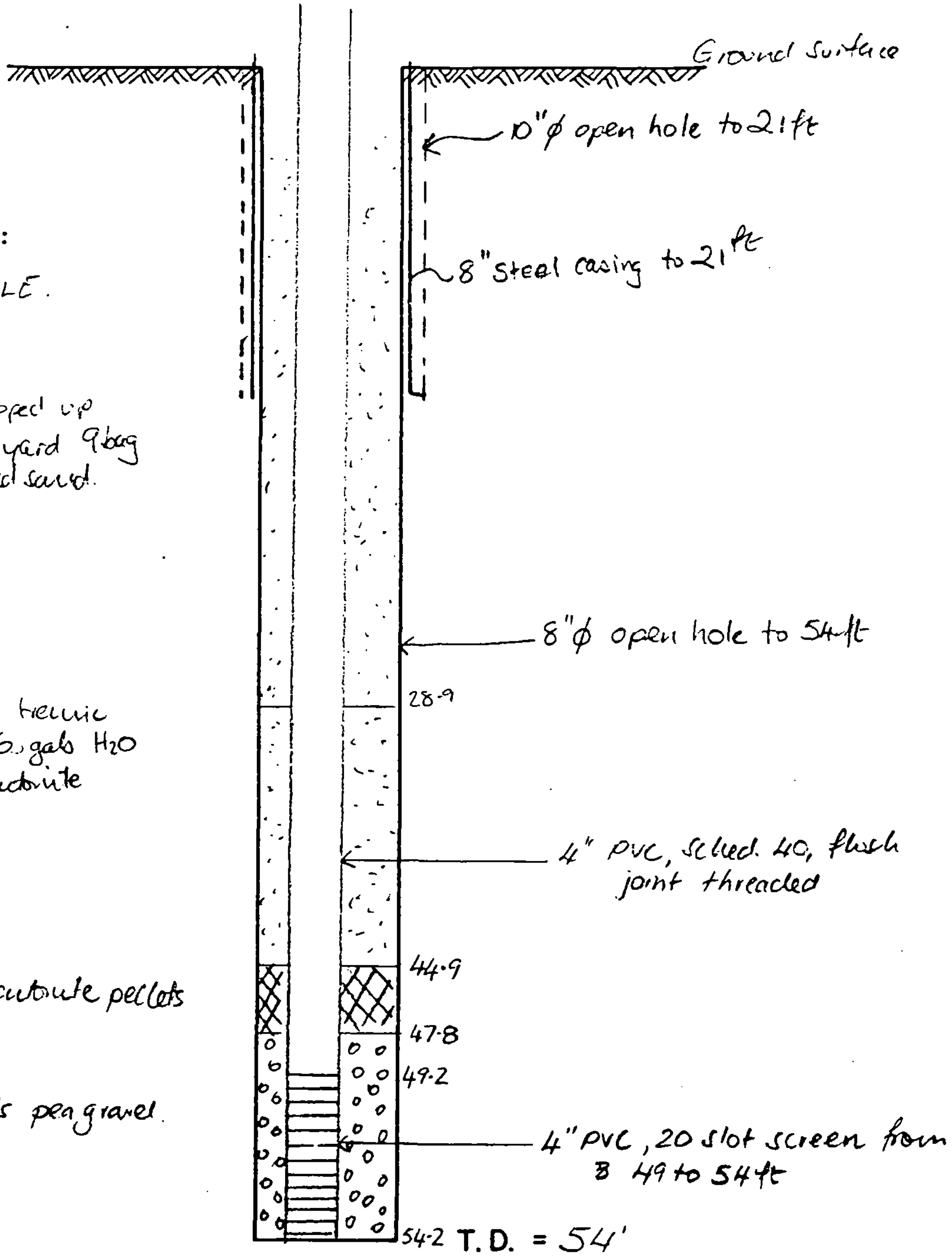
iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA

Figure

BOREHOLE TW36

HOLE DIAMETER 10" 0-21'
8" 21-54'



REMARKS:

NOT TO SCALE.

Hole topped up with ½ yard 9 bag grout and sand.

Pumped grout via tremie est 10 bags x 5.6 gals H_2O with some bentonite + flocele.

1x 50lb pail bentonite pellets

8 x 5 gallon pails pea gravel

PROJECT .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW36
Sheet 1 of 1

Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: Air / Water

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) ~~Other~~ Pen. Rate mins/ft	After Drilling (2)(7) Water Level ~~(m)~~ T°C	Permeability (8) (2) Depth (m) Cu/cm	Method pH	Value (cm/s) F (mg/L)	Comments
Ground Surface										
Brown silty CLAY 2	10" 8" 4				1.5					
Black slightly to mod. weathered BASALT (10) 18					2.4					
					2.0					
					3.0					
Fresh grey BASALT (20) (30) (40)	21				4.7					
					5.4					
					3.0					
					5.6					
	45 48			<1	5.6	1.0	750	7.2	11.5	
(50)					5.8					
Red/brown CINDERS									13.0	Could not lift much water from borehole
Fresh grey BASALT 54	54	54	23.8	—	1.0					
End of Borehole. (60)										

Contractor: Andrew Well Drilling
Date started: 1st Feb 1985
Date finished: 2nd Feb 1985
Logged by: DB/MS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale: —

HISTORY OF HOLE

TW36

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/01/85

3:25	Started drilling TW36 10"Ø open hole.
4:16	Drilled 10"Ø to 21', overburden 2' then weathered basalt to 18', fresh grey basalt to 21'.
4:16 - 4:40	Pulled out 10" bit, set 21'6" of 8" casing in hole to 21' below ground level.
4:40	Restart drilling at 8"Ø.
5:15	Stopped drilling at 28/29' in fresh grey basalt.

DATE: 02/02/85

7:50	Started drilling 8"Ø, picked up trickle of water at 41'. Very little return, probably due to the fact that the 900 compressor was not used. Water sample from 47', F = 11.5 mg/l.
9:49	Drilled to 51' through fresh grey basalt. At 51 to 53' encountered cinders, no water made but driller managed to lift water sample from hole - F = 13.5 mg/l; encountered fresh grey basalt at 53 to 54'.
9:50	Stopped drilling.
9:50 - 11:00	Drillers fixing wrench.
11:00 - 11:45	DB and MS log hole for natural gamma and resistivity.
11:45 - 12:30	Lunch.
12:30 - 2:00	Completed well. Set 3x20' 4" blank PVC + 1x5' 20 slot screen in hole; 2 centralizers. Could not use teflon tape on joints due to cold weather. Screen set 54 to 49', gravel packed with 8x5 gal pails gravel to 47.8'. 1x50 lb pail bentonite pellets to 44.9'.
1:53	Depth to water = 8.23 m (27.00') below PVC pipe.

HISTORY OF HOLE

TW36

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/13/85

4:00 Move back over TW36, run tremie pipe to 40'. Pump cement remaining from TW35 and TW39 into hole. Estimate approximately 10 bags + 60 gals water pumped into hole with bentonite and Flocele (see sheet for TW35 for grout mix).

4:45 Finished pumping, moved off hole.

DATE: 02/14/85

Sounded grout to 8.8 m (28.9'). Added about 1/2 yd 9 bag cement sand mixture to fill hole to surface.

WELL DEVELOPMENT - TW36

TW36 was developed on February 12th, 1985. One inch diameter pipe was set at a depth of 39 ft and the well airlifted at a rate of 5 to 8 gpm for 30 mins. The water was clean. Chemical parameters of the airlifted water were measured during development.

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH
5	9.0	1025	6.85
28	7.5	1010	6.86
40	8.5	1010	6.89
50	8.0	1000	6.90

F = 11.2 mg/l

<u>TW 37</u>

i) Schematic Test Well Completion

ii) Field Borehole Log

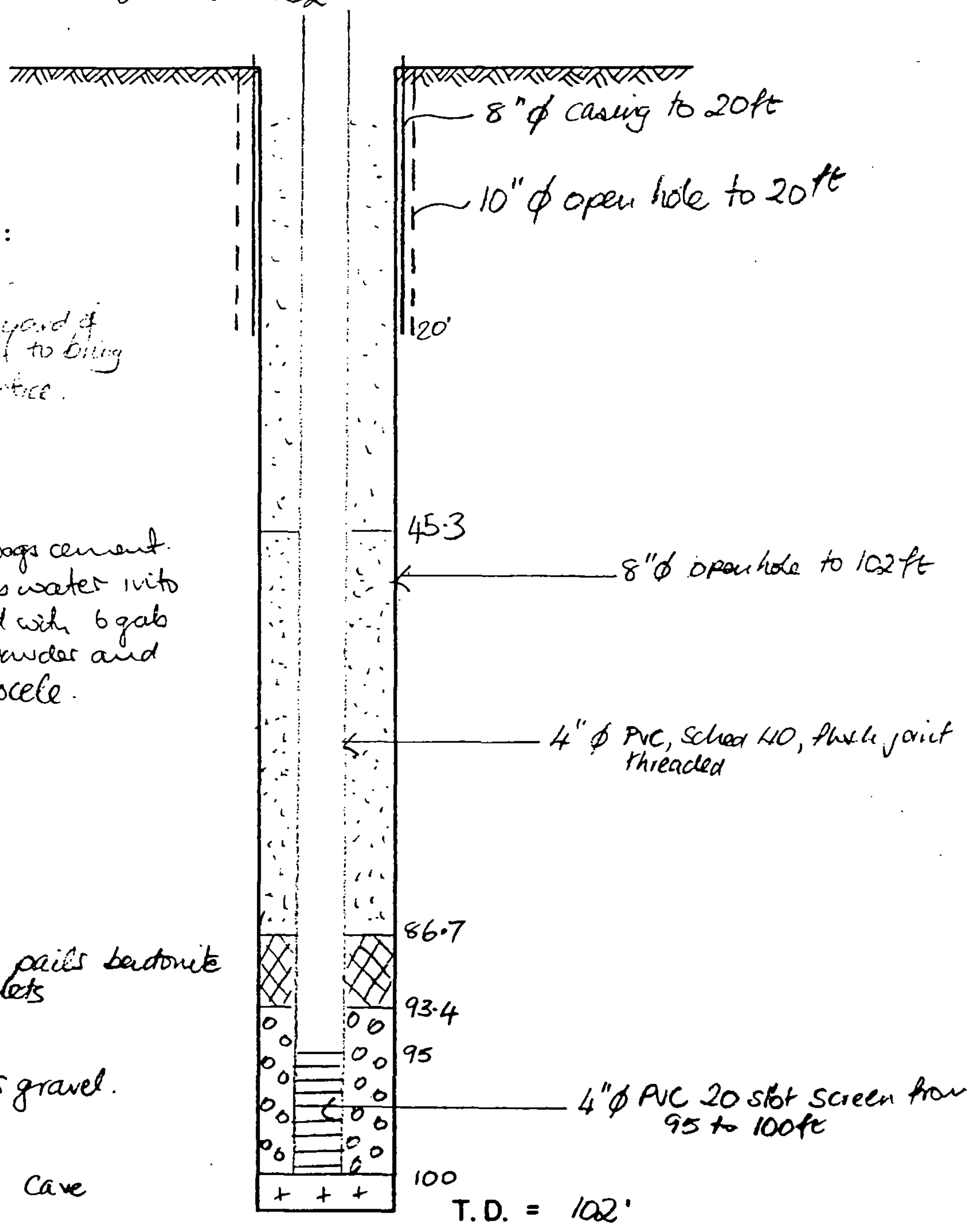
iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA

PIEZOMETER INSTALLATION DATA	Figure

BOREHOLE TW 37

HOLE DIAMETER 10" 0-20'
8" 21-102'



REMARKS:

Not to Scale.

Approx ½ yard of 9 bag grout to bring hole to surface.

Pumped 40 bags cement with 240 gals water into hole. Mixed with 6 gals bentonite powder and 5-7lbs of flocele.

2 x 50lb pails bentonite pellets

17 x 2 gal pails gravel.

Cave

PROJECT .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW37
Sheet 1 of 2

Job No.

Project: MONSANTO GROUNDWATER STUDY

Type of drilling: ROTARY

Rig: SCHRAMM T-64

Drilling fluid: AIR/WATER

Coordinates: E .... N ....

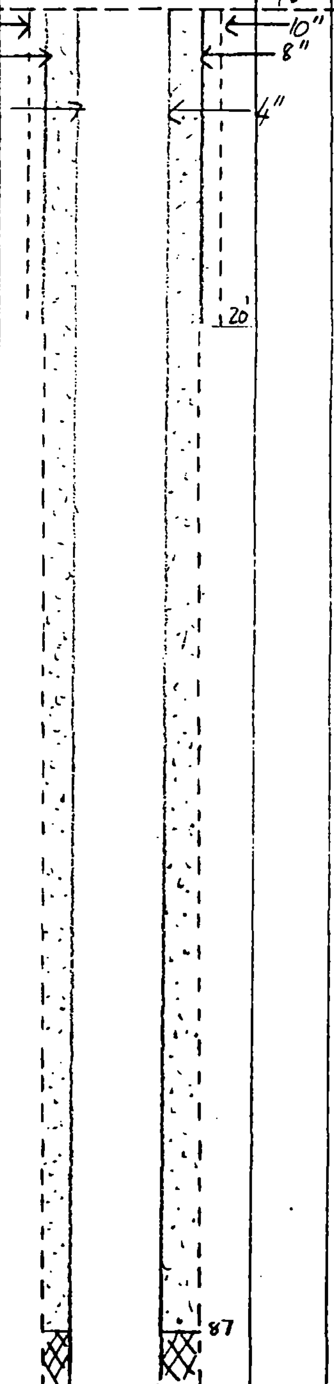
Angle from horizontal: 90°

Bearing: — °Azimuth

Reference elevation: ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole: MONITORING WELL

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2)(4) Water Level ~~(m)~~	(5) Water Flow ~~(l/s)~~	(6) ~~Other~~ Pen. Rate	After Drilling (2)(7) Water Level (m)	Permeability (8) (2) Depth (m)	Method	Value (cm/s)	Comments
Ground Surface		ft	ft	gpm	mins/ft	T?	C.4	ft	F(ugh)	
Brown Silty CLAY 5										
Black slightly to moderately weathered BASALT 13					1.0					
					7.0					
					3.5					
					4.0					
Fresh grey BASALT					2.0					
					3.0					
					3					
					6					
					5					
					5					
					4					
				none	5					
					6					
				none	6					
					8					
				none	6					

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling

Date started: 4th Feb 1985

Date finished: ....

Logged by: DB/MS.

Checked by: ....

Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW37
Sheet 2 of 2

Job No.

Project ....

Type of drilling .... Coordinates: E ....

Rig .... N ....

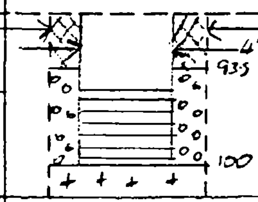
Drilling fluid .... Angle from horizontal ....

Bearing .... °Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2) (4) Water Level (m)	(5) Water Flow ~~(l/s)~~	(6) ~~Other~~ Pen Rate	After Drilling (2) (7) Water Level ~~(m)~~	Permeability (8) (2) Depth (m)	Method	Value (cm/s)	Comments
Cont'd		ft	ft	gpm	min/ft					
90 Fresh grey BASALT 95	 4" 8" 93.5 100	8"		none	6					
Fractured BASALT and CINDERS 100 102					3					Cuttings and water lost at 95'
		102	65.4	—	1					
End of Borehole										
110										

Contractor: .... Logged by: ....

Date started: .... Checked by: ....

Date finished: .... Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW37

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/04/85

1:15 - 2:40	Move and set up at TW37.
2:40 - 3:45	Drilled 10"Ø to 0 to 21'; overburden at 0 to 5', weathered basalt at 5 to 13', fresh grey basalt at 13 to 21'.
3:45 - 3:55	Set 8"Ø casing to 21', s/u = 1'6".
3:55 - 5:25	Drilling 8"Ø open hole 21 to 49' - fresh grey basalt.

DATE: 02/05/85

7:40 - 12:05	Drilling 8"Ø open hole 49 to 102'. Fresh grey basalt to 95', then fractured basalt and cinders at 95 to 102'. Loose circulation of cuttings at 95'. Hole dry until 95', water level = 65.4'.
12:05 - 1:30	Drillers take lunch and repair hydraulic hose.
1:30 - 1:45	Replace hydraulic hose.
1:45 - 2:00	Pull out rods.
2:00 - 3:00	Log hole with Monsanto logger, natural gamma and resistivity. Hole caved to approximately 100'.
3:00 - 5:00	Complete well, set 1x5' 20 slot PVC screen + 5x20' blank PVC 4"Ø in hole; 3 centralizers. Screen set at 100 to 95'. Gravel packed with 17x2 gal pails gravel to 100 to 93.4'; 2x50 lb pails bentonite at 93.4 to 86.7'.

DATE: 02/13/85

5:00	Move rig and set up on TW37, run 1" tremie pipe to 80'.
5:30	Move mixer to site.

HISTORY OF HOLE

TW37

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/14/85

7:45	Ordered 40 bags + 260 gals water from Parsons.
9:00	Cement truck arrives. Add approximately 6 gals volume bentonite and 5 to 7 lbs Flocele to cement mixture - mixed for 20 to 25 mins. Started pumping but could not pump cement into hole. Pulled out first tremie pipe from top and then pumped cement from 60'.
10:10 - 10:30	Cleaning out tremie pipe and mixer.

DATE: 02/15/85

Sounded grout to 13.8 m (45.3') below surface.

WELL DEVELOPMENT - TW37

TW37 was developed on February 12th, 1985. One inch diameter tremie pipe was set to a depth of 80 ft and the well airlifted at a rate of 2 to 3 gpm for 1 hour. The water was dirty brown at the start of development, but cleared up. Stevens water level recorder monitored the response of TW5 during development. Manual depth to water measurements were taken on TW6. The chemical parameters recorded are given below:

Elapsed Time (mins)	T °C	C (µmhos/cm)	pH
9	9	1775	6.94
25	9	1650	6.95
40	9	1650	7.04
60	8.5	1650	7.09

F = 21.5 mg/1

The water level in TW6 drew down 0.03 ft, while no detectable response was seen in TW5 during development.

TW 38

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA | Figure

BOREHOLE TW38

HOLE DIAMETER 10" to 42'
8" 42-102'

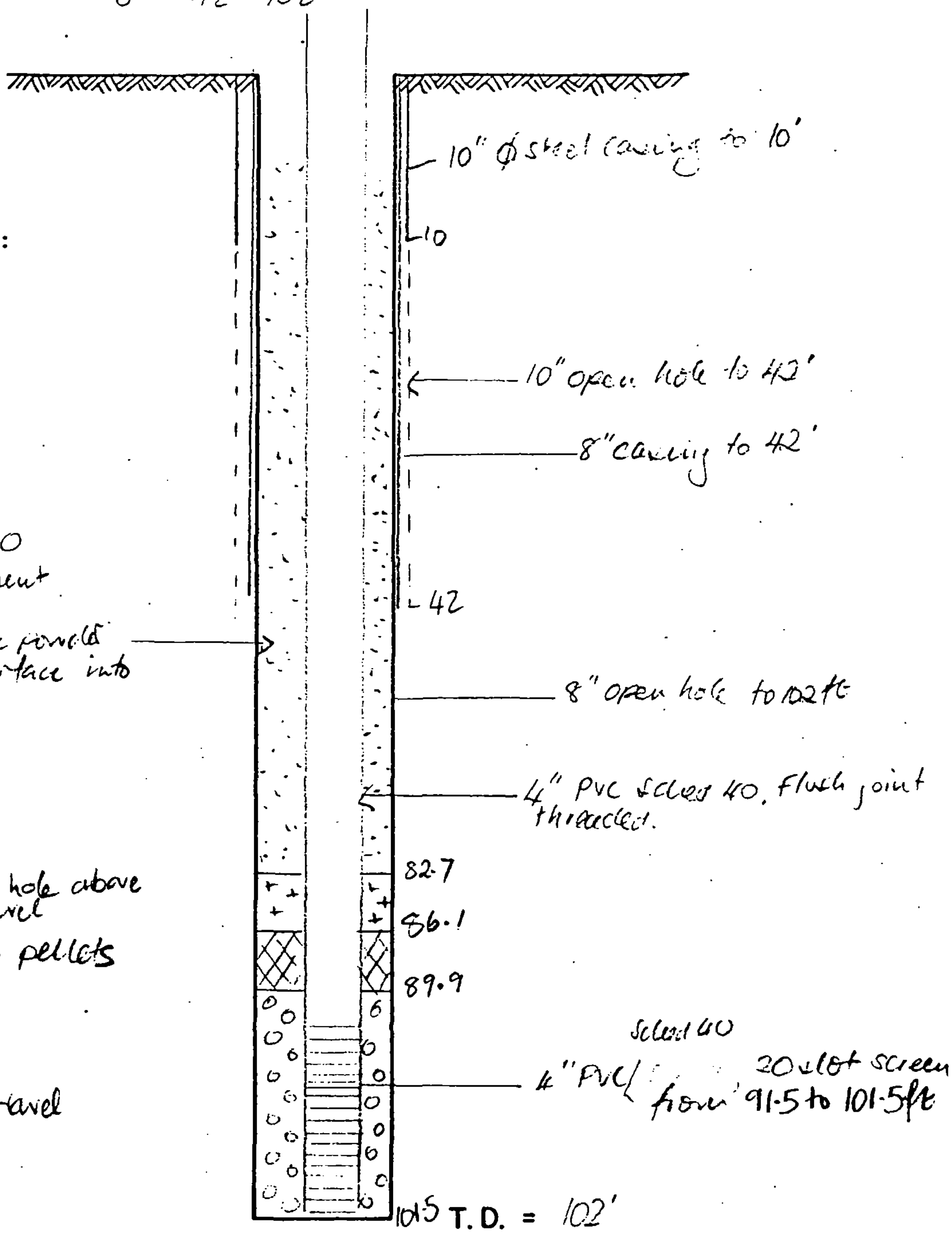
REMARKS:

cement slurry
est'd 200 gals H_2O
40 bags cement
12½ lbs flocele
50 lbs bentonite powder
poured from surface into
dry hole

Cuttings to bring hole above water level

100 lb bentonite pellets

11x2gal pails gravel



PROJ. NO. .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW38 — Sheet 1 of 2

Job No.

Project	MONSANTO GROUNDWATER STUDY
Type of drilling	ROTARY
Rig	SCHRAMM T-64
Drilling fluid	AIR/WATER
Coordinates: E	
N	
Angle from horizontal	90
Bearing	— °Azimuth
Reference elevation	
Elevation type: surveyed ☐ altimeter ☐ from map ☐	
Purpose of hole	MONITORING WELL

(1) (2)* Lithology	(2) (3) Completed Construction	During Drilling: (2) Depth ~~(m)~~ ft	(2)(4) Water Level ~~(m)~~ ft	(5) Water Flow ~~(l/s)~~ gpm	(6) ~~Other~~ Pen. Rate min/ft	After Drilling: (2)(7) Water Level ~~(m)~~ T°C	Permeability (8): (2) Depth (m) C.u/cm	Method pH	Value (cm/s) F (mg/l)	Comments
Ground Surface										
SLAG 2	10"									
Brown silty CLAY	8"									
10	4"									
10	10									
Fresh grey BASALT					5·0					
20					5·0					
					5·5					
30					6·0					
					6·5					
40	42				4·5					
50					5·0					
55					3·0					
Red/Brown SILT 57										
60 Red/brown mod. weathered BASALT and silty CLAY					1·0					
					2·0					
70 71					5·0					
Fresh grey BASALT					3·0					
80					5·0					
	86				3·5					
88										
90 Red/brown CINDERS				1-2	4·0					

Contractor:	Andrew Well Drilling
Date started:	5th February 1985
Date finished:	11th February 1985
Logged by:	DB/MS
Checked by:	
Date:	

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HYDROGEOLOGIC LOG

DRILLHOLE No. TW38
Sheet 2 of 2

Job No. ....

Project ....

Type of drilling .... Coordinates: E ....
N ....

Rig ....

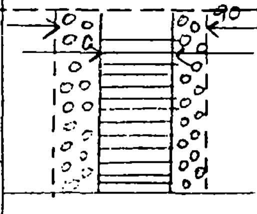
Drilling fluid .... Angle from horizontal ....

Bearing .... °Azimuth

Reference elevation ....

Elevation type: surveyed ☐ altimeter ☐ from map ☐

Purpose of hole ....

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	During Drilling (2)(4) Water Level ~~(m)~~	During Drilling (5) Water Flow ~~(l/s)~~	During Drilling (6) ~~Other~~ Pen. Rate	After Drilling (2)(7) Water Level ~~(m)~~	After Drilling Permeability (8) ~~(2) Depth (m)~~	After Drilling Permeability (8) ~~Method~~	After Drilling Permeability (8) Value (cm/s)	Comments
		ft	ft	gpm	mins/ft	T°C	C µS/cm	pH	F (mg/l)	
90 Contd										
90 Red/brown CINDERS 100	 90	8" 4"	84.6	5	4.0 1.0 2.0	8	600	7.10	1.08	
100 Fresh grey BASALT 102										
End of Borehole										

Contractor: .... Logged by: ....
Date started: .... Checked by: ....
Date finished: .... Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW38

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/05/85

4:30 - 5:00	Move and set up at TW38.
5:00 - 5:40	Drilled 10"Ø open hole 0 to 15', encountered slag at 0 to 2', silty clay at 2 to 10' and fresh grey basalt at 10 to 15'.

DATE: 02/06/85

7:30 - 8:10	Warm up rig. Set 10' 10" casing.
8:10 - 10:35	Drilling 10"Ø open hole 15 to 42' through fresh grey basalt.
10:35 - 12:00	Pull out 10" drill stem, drillers go to pick up 8" casing. Set two lengths of 8" casing - total length = 44'. Cut off 3'3" and set casing at ground level, therefore casing set at 41'9".
12:00 - 1:00	Lunch.
1:00 - 1:25	Drillers fetch fuel truck.
1:25 - 5:20	Drilling 8"Ø open hole from 42 to 102'; encountered fresh grey basalt at 42 to 55', red/brown silt at 55 to 57', weathered basalt and silt at 57 to 71', fresh grey basalt at 71 to 88', cinders and water at 85 to 100', and fresh grey basalt at 100 to 102'. Water hit at 88' - hole makes 5 gpm by 100'. Fluoride analysis from 97' - F = 1.08 mg/l.
5:20 - 5:30	Pull out 8"Ø drill stem. Depth to water = 25.8 m (84.64') below ground level.

DATE: 02/07/85

7:30 - 8:25	Log hole using Monsanto logger, natural gamma and resistivity.
8:25 - 10:00	Set 10' 20 slot screen (2x5' lengths) and 4x20' blank 4"Ø PVC pipe and 2x10' blank 4"Ø PVC pipe. Gravel pack screen with 11x2 gal pails gravel from 101.5 to 89.9'. Add 100 lbs bentonite pellets 89.9 to 86.1'.

HISTORY OF HOLE

TW38

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/11/85

Depth to water outside PVC approximately 85' (i.e. 1-1/2' water in hole). Add 3-1/2' of fine cuttings to borehole on top of bentonite. Pour approximately 200 gals cement slurry into hole (no water in hole) - 40 bags + 12-1/2 lbs Flocele + 50 lbs bentonite powder.

WELL DEVELOPMENT - TW38

TW38 was developed on February 12th, 1985. One inch diameter tremie pipe was set to a depth of 102 ft (bottom of the well) and the well air-lifted at a rate of about 1/2 gpm. The water was clear. There are no other wells at this location. The chemical parameters of the airlifted water are given below:

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH
11	4.5	575	7.23
20	3.5	525	7.26
35	3.5	550	7.31

F = 0.62 mg/l

TW 39

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA

Figure

BOREHOLE TW39

HOLE DIAMETER 10" 0 - 23'
8" 23 - 57'

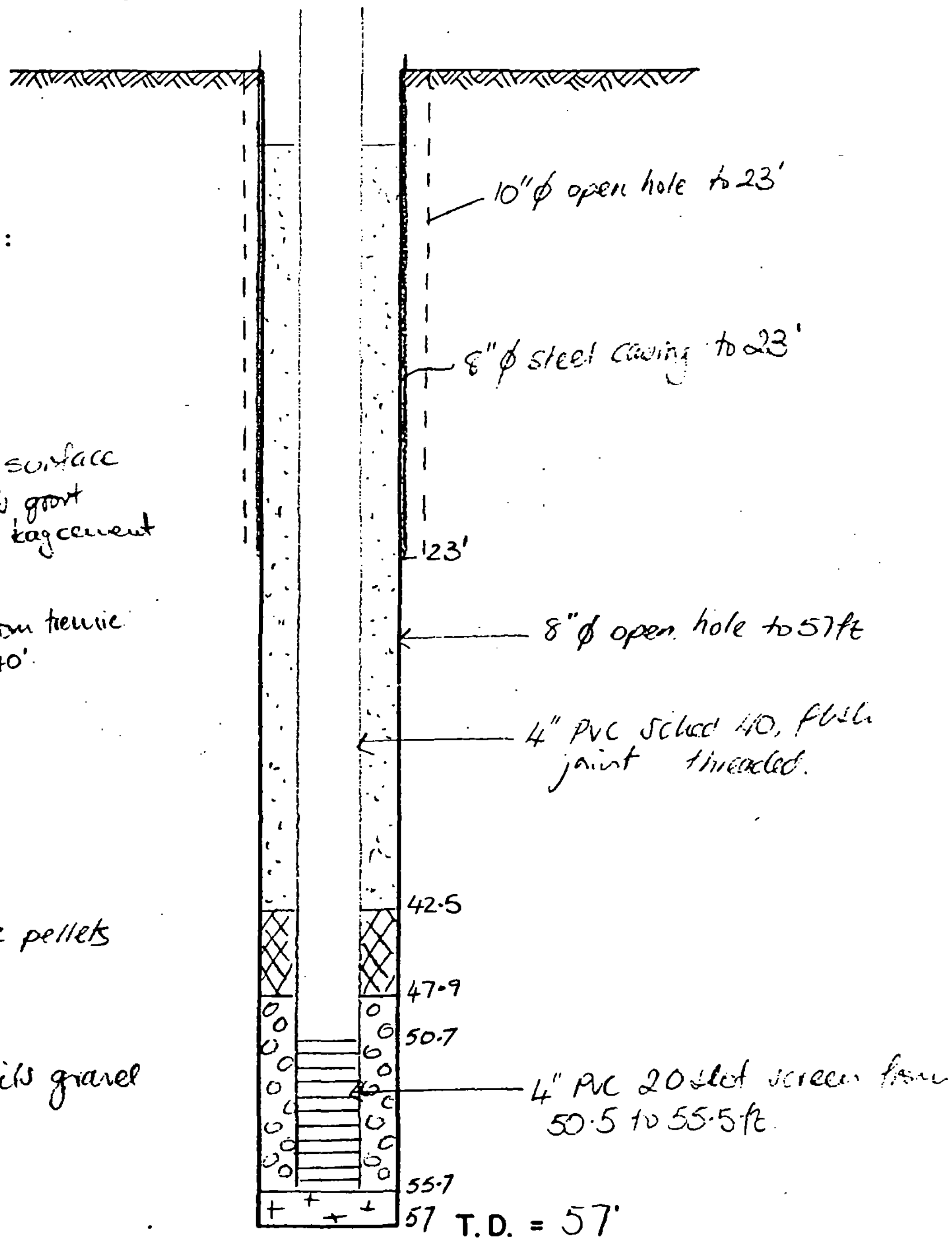
REMARKS:

Grouted to surface
with est 100 gals grout
6 gals water per bag cement
+ bentonite
+ flocle
grout pumped from tremie
pipe set at 40'

100 lb bentonite pellets

20 x 2 gal pails gravel

Cave



PROJECT NO. DRAWN REVIEWED DATE

HYDROGEOLOGIC LOG

DRILLHOLE No. 7639
Sheet 1 of 1

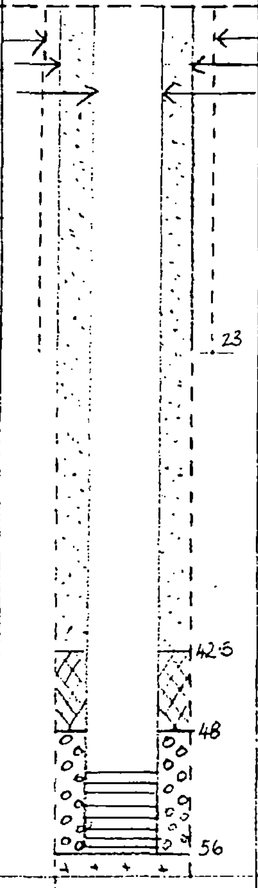
Job No.

Project: MONEMINTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: AIR/WATER

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation: ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	(2)(4) Water Level ~~(m)~~	(5) Water Flow ~~(l/s)~~	(6) Other Pen. Rate	After Drilling (2)(7) Water Level (m)	Permeability (8) (2) Depth (m)	Method	Value (cm/s)	Comments
Ground Surface		ft	ft	gpm	min/ft				F(ngl)	
Brown silty CLAY 1										
Fresh grey BASALT 4					1·5					
Black sl. to mod weathered BASALT some silt. 12					1·5					
10					1·5					
Fresh grey BASALT 14										
Red/brown mod. weathered BASALT and silt. 22					1·5					
20					5·0					
					4·0					
30 Fresh grey BASALT.					3·5					
					3·0					
40					4·0					
					7·0					
50 51					11·0					
Red/brown CINDERS 56				75-100	/				8·0	
Fresh grey BASALT 57										
End of Borehole										
60										



Contractor: Andrew Well Drilling
Date started: 7th February 1985
Date finished: 8th February 1985

Logged by: DB/MS
Checked by: ....
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW39

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/02/85

12:45	Set up to drill TW39.
12:45 - 2:00	Lunch.
2:00 - 2:30	Drillers cleaning up cardboard at trailor.
2:45 - 3:32	Drilling 10"Ø open hole 0 to 23'. Encountered brown silty clay at 0 to 1', fresh grey basalt at 1 to 4', slight to moderate weathered basalt and some silt at 4 to 12', fresh grey basalt at 12 to 14', red/brown moderately weathered basalt and silt at 14 to 22', and fresh grey basalt at 22 to 23'.
3:32 - 3:52	Set 8" casing to 23'.
3:52 - 5:33	Drilling 8"Ø open hole 23 to 46-1/2', all fresh grey basalt. Cuttings damp at 32', but hole does not make any water.

DATE: 02/08/85

7:30 - 8:35	Drilling borehole 8"Ø open hole 46-1/2 to 57', hit cinders at 51 to 46' - 75 to 100 gpm - fresh grey basalt at 56 to 57'. Fluoride sample from 55' = 8.0 mg/l.
8:35 - 10:00	Logging hole using natural gamma and resistivity tools.
10:00 - 12:00	Set PVC - 5' screen 55-1/2 to 50-1/2' 4"Ø, 4" blank PVC to surface. Gravel pack screen to 47.9' with 20x2 gal pails gravel - 100 lb bentonite pellets 47.9 to 42.5'.

DATE: 02/13/85

3:20	Moved back over hole. Ran tremie pipe to 40'. Pumped about 20 bags with 120 gals water + bentonite and Flocele into borehole - hole overflowed at surface with grout. (Mixture taken from delivery for TW35.)

WELL DEVELOPMENT - TW39

TW39 was developed on February 14th, 1985. One inch diameter tremie pipe was set to a depth of 39 ft and the well airlifted at approximately 20 to 25 gpm for 1 hour. A Stevens water level recorder monitored the response in TW35. The chemical parameters of the airlifted water were measured during development and are given below:

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH
5	5.0	1010	9.40
23	3.5	950	8.16
40	6.0	1010	7.84
60	6.0	1010	7.69

F = 9.7 mg/l

TW35 showed no response to the development of TW39 (see TW35 Stevens Chart #1). TW20, approximately 350 ft east of TW39, drew down 0.015 ft (see Stevens Chart #10 - TW20) over the same period.

<u>TW 40</u>

i) Schematic Test Well Completion

ii) Field Borehole Log

iii) History of Hole and Well Development

PIEZOMETER INSTALLATION DATA

Figure

BOREHOLE TW40

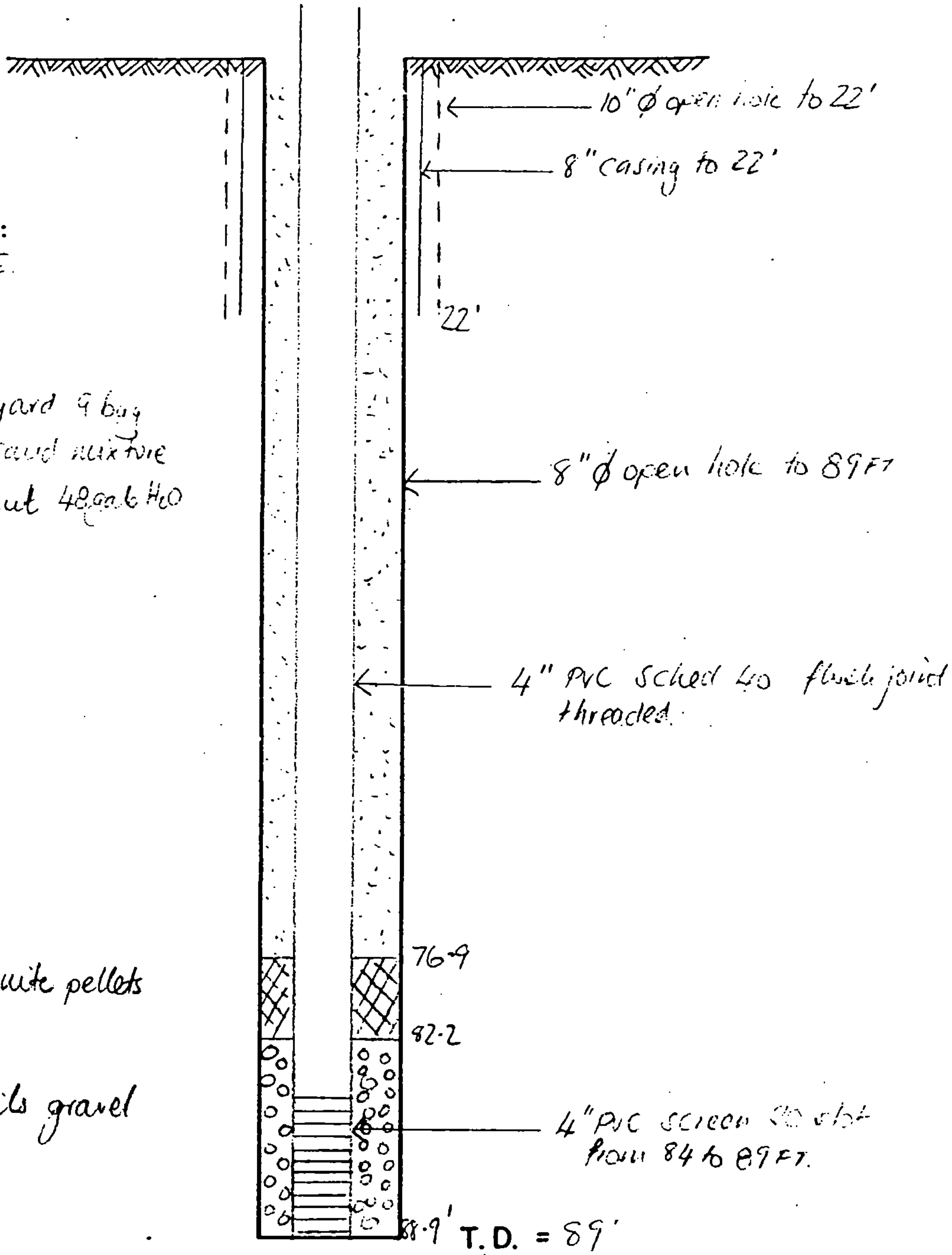
HOLE DIAMETER 0-22' 10" ø
22-89' 8" ø

REMARKS:
NOT TO SCALE.

GROUT - 1 yard 9 bag cement/sand mixture
9 bag cement 48 gal H_2O + sand.

100 lb bentonite pellets

12 x 2 gal pails gravel



T.D. = 89'

PROJECT NO. .... DRAWN .... REVIEWED .... DATE ....

HYDROGEOLOGIC LOG

DRILLHOLE No. TW 40
Sheet 1 of 1

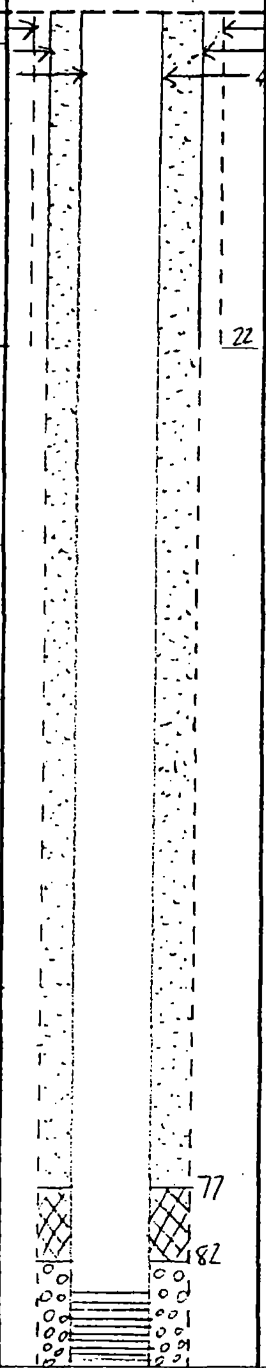
Project: MONSANTO GROUNDWATER STUDY
Type of drilling: ROTARY
Rig: SCHRAMM T-64
Drilling fluid: Air/Water

Coordinates: E .... N ....
Angle from horizontal: 90°
Bearing: — °Azimuth

Reference elevation: ....
Elevation type: surveyed ☐ altimeter ☐ from map ☐
Purpose of hole: MONITORING WELL

Job No.

(1) (2) * Lithology	(2) (3) Completed Construction	During Drilling (2) Depth ~~(m)~~	During Drilling (2) (4) Water Level ~~(m)~~	During Drilling (5) Water Flow ~~(l/s)~~	During Drilling (6) ~~Other~~ Pen. Rate	After Drilling (2) (7) Water Level ~~(m)~~	~~Permeability (8)~~ ~~(2) Depth (m)~~	Permeability (8) Method	Permeability (8) Value (cm/s)	Comments
Ground Surface		ft	ft	gal/m	min/ft				E(mg/L)	
0–2 SLAG					1					
2–22 Brown silty CLAY					1					
					1.5					
22–35 Fresh grey BASALT					1.5					
					3.5					
35–45 Red/brown sandy SILT					3.0					
					1					
					1					
45–56 Fresh grey BASALT					2					
56–56.5 ~~Brown sandy SILT~~										
56.5–63.5 Fresh grey BASALT					1					
					1					
63.5–64 ~~Brown Sandy SILT~~					3					
64–84 Fresh grey BASALT					2.5					
					2.5					
					4.0					
84–89 Red/brown scoriaceous CINDERS		89	82	3-5	2.0				11.0	
90 End of Borehole										



Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

Contractor: Andrew Well Drilling
Logged by: MS/DB
Date started: 17th Feb 1985
Checked by: ....
Date finished: 17th Feb. 1985
Date: ....

* NOTE: Bracketed numbers refer to notes preceding the logs.

Golder Associates

Scale:

HISTORY OF HOLE

TW40

GEOLOGIST: D. Banton / M. Shaleen DATE: 02/17/85

8:00 - 8:15	Set up to drill TW40 - allowed rig to warm up.
8:15 - 8:55	Drilling 10"Ø open hole 0 to 22' - silty clay (moist), bedrock at 22'.
8:55 - 9:05	Set 8" casing to 22' (no shoe), casing is 23'6" long.
9:05 - 9:55	Drilling 8"Ø open hole 22 to 35'.
9:55 - 10:35	Drillers pick up 900 compressor to help blow out hole.
10:35 - 12:05	Drilling 8"Ø open hole to 82'.
12:05 - 1:10	Drilling 8"Ø open hole 82 to 89'; encountered fresh grey basalt at 22 to 35', brown sandy silt at 35 to 45', fresh grey basalt at 45 to 56', sandy silt at 56 to 56-1/2', fresh grey basalt at 56-1/2 to 63-1/2', sandy silt at 63-1/2 to 64', fresh grey basalt at 64 to 84', and cinders at 84 to 89'. Hole dry until 84' - makes 3 to 5 gpm at 89'. Fluoride measurement, F = 11 mg/l.
1:15 - 2:00	Log hole using natural gamma and resistivity tools.
2:00 - 3:20	Set 5' 20 slot PVC screen 89 to 84'. Blank PVC to surface. Gravel pack borehole with 12x2 gal pails gravel to 82.2' + 100 lb bentonite pellets to 76.9'.
5:00	Grout in PVC with 1 yd 9 bag grout delivered by Parsons, set protective steel casing.

WELL DEVELOPMENT - TW40

TW40 was developed on February 17th, 1985. One inch diameter tremie pipe was set to a depth of 89 ft (bottom of well) and the well airlifted for approximately 30 mins. The well yielded 1/2 gpm of water or less and was red/brown in colour. Two water samples were collected during development:

Elapsed Time (mins)	T °C	C (μmhos/cm)	pH
13	9	3450	7.01
30	5.5	3275	7.13

F = 11.0 mg/1

Development stopped since only a very small amount of water (<1/4 gpm) was being blown from the well. The well recovered to within 3 in. of the original static water level within 25 mins of development ending.

APPENDIX E

GEOLOGICAL PHOTOGRAPHS

PLATE 1 Typical fault bounded graben type depression north of Soda Springs.

PLATE 2 Typical exposure of massive basalt. Notice near-vertical and horizontal jointing pattern and blocky nature of basalt.

PLATE 3 Close up of massive basalt. Notice vertical jointing and vesicular nature of basalt.

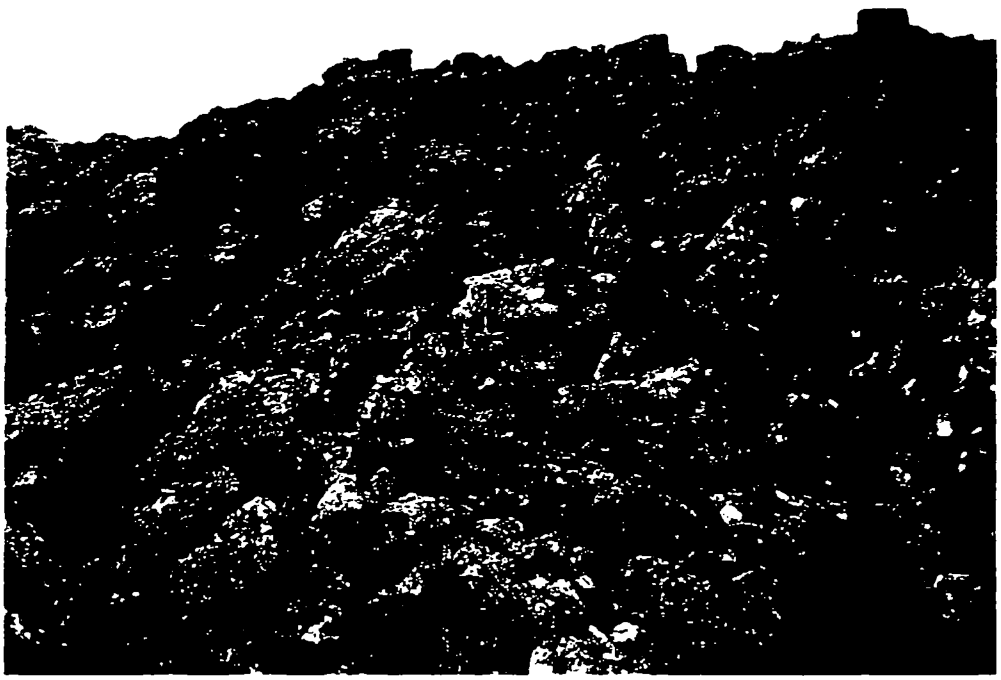


PLATE 4 Columnar basalt exposed at the edge of a flow or along fault plane. Note open work nature of fracture system.

PLATE 5 Salt Lake Formation - sandstone and conglomerate at NE 1/4, SW 1/4, Sec 42, T10S R42E

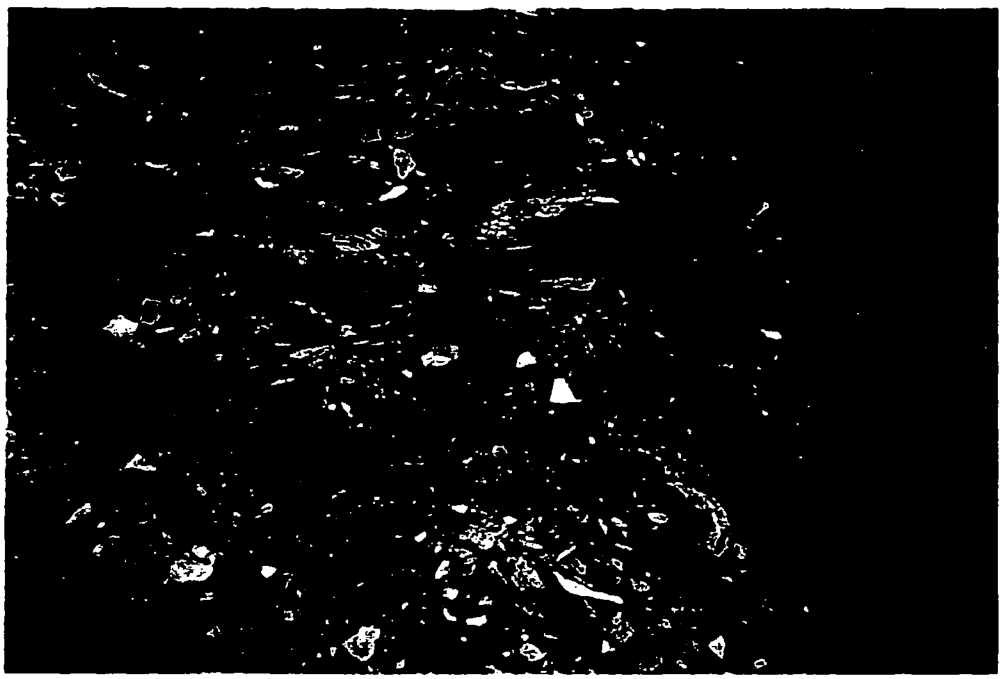


PLATE 6 Salt Lake Formation - tuffaceous sandstone exposed at NW 1/4, SE 1/4, Sec 3, T10S R42E.

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		Checked by	Date
		Approved by	Sheet No. 1

PUMP TEST ANALYSES

A variety of single and multiple borehole pump tests were conducted at the site to obtain in situ measurements of hydraulic parameters. Single borehole tests provided transmissivity values for the intervals tested and also allowed for qualitative assessment of leakage through adjacent confining ~~[illegible]~~ units. Data from multiple borehole tests were used to calculate transmissivity, storativity, and in one case, a lower bound value of vertical hydraulic conductivity for an adjacent confining unit.

F.1 Analysis of Single Borehole Tests

Single borehole pump tests were conducted in six existing test wells (TW-3, 4, 5, 6, 7, 8,) and in two wells drilled during the field program (TW-9, 10). Tests were generally performed by operating an electric submersible pump for approximately one hour, with water level monitoring of both the pumping and recovery periods (constant discharge tests). In three cases, pumping was prematurely terminated when water level in the well reached the pump intake. For these tests, only the recovery period was analyzed (slug tests). During five tests (TW-3, 4, 5, 6, 7) water levels were monitored in a test well adjacent to the pumping well to determine if a vertical hydraulic response could be measured.

Constant Discharge Tests For wells pumped at a more or less constant discharge rate (TW-3, 5, 6, 7, 10), pumping period data were analyzed using the Jacob semilog method (Cooper and Jacob, 1946) and recovery data were analyzed using Theis (1935) recovery plots. For these tests, average flow rate was calculated from the slope of a graph of cumulative discharge volume vs. pumping time, based on data obtained from a totalizing flow meter. Pumping period data were analyzed by preparing Jacob semilog plots of drawdown (s) vs. log of pumping time (t), and fitting a straight line to the

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		Checked by	Date
		Approved by	Sheet No. 3

data. Transmissivity (T) was then calculated using the following equation:

$$T = \frac{2.303\,Q}{4\pi\,(\Delta s)} \qquad (1)$$

where

Q = pumping discharge rate

Δs = change in drawdown per log cycle of the semilog straight line.

Recovery data were analyzed by preparing Theis recovery plots of drawdown (s) vs. the log of (t/t') where

t = time since beginning of pumping

t' = time since beginning of recovery.

After fitting a straight line to the data, transmissivity was calculated using equation (1). Both Jacob and Theis recovery plots can be affected by wellbore storage, hydrologic boundaries, aquifer leakage, etc. As a result, a straight line can usually be fitted only to a portion of the data, leading to a certain degree of subjectivity in the analyses.

Slug Tests For wells evacuated of water by short term pumping (TW-4, 8, 9), recovery data were analyzed using a modified Hvorslev (1951) slug test method. To perform the analysis, a semilog plot of log of drawdown

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		Checked by	Date
		Approved by	Sheet No. 4

(s) vs recovery time (t') was prepared, and a straight line fit to the data. Transmissivity was then calculated using the following equation:

$$T = \frac{2.303\,AC}{2\pi\,(t_2' - t_1')} \log\left(\frac{s_1}{s_2}\right) \qquad (2)$$

where

A = cross-sectional area of riser pipe

C = shape factor (assumed equal to 6.2)

t_n' = recovery time for an arbitrary point on the semilog straight line

s_n = drawdown for an arbitrary point on the semilog straight line.

For calculations performed herein, a riser pipe area of $8.18 \times 10^{-2}\ f^2$ was assumed. This corresponds to the annular space between a 1 inch OD pump column and ~~a~~ 4 inch ID well casing.

Test Results The results of constant discharge tests are summarized in Table F-1 and associated water level hydrographs, Jacob semilog plots, and Theis recovery plots are shown in Figures F-1 through F-14. Slug test results are summarized in Table F-2 and associated hydrographs and modified Hvorslev plots are are shown in Figures F-15 through F-18. Water level hydrographs are given only for those tests where water levels were monitored in an adjacent test well.

Transmissivity values from the single borehole tests range over four orders of magnitude (.52 to 9700 f^2/d). This would suggest a nonhomogeneous system; probably consisting of high permeability cinder zones interbedded with low permeability (confining) units of dense basalt. Single hole tests are generally considered to provide order-of-magnitude estimates of transmissivity for materials in ~~the~~ immediate vicinity of the test well. As such, they do not directly provide large scale hydraulic parameter values suitable for quantification of a site conceptual model. It should also be noted that slug tests can be significantly affected by "wellbore damage", which may result from a zone of drilling mud invasion adjacent to the well or head losses in a partially clogged well screen. If wellbore damage is significant, slug tests would tend to underestimate the transmissivity of the undisturbed formation. Since detailed drilling records are not available for ~~the~~ pre-existing wells, it can not be determined if wellbore damage may have had a significant effect on slug tests conducted in TW-4 and TW-8.

Measurable drawdowns occurred in all cases where water levels were monitored in an adjacent test well

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		Checked by	Date
		Approved by	Sheet No. 6

during pumping. Since adjacent wells were completed at different depths from the pumping wells, this is interpreted to indicate that confining units have sufficiently high ~~[illegible]~~ hydraulic conductivity to allow a vertical hydraulic response within the time frame of the tests. In addition, Jacob semilog and Theis recovery plots for TW-5 and 7 show characteristics which could be indicative of aquifer leakage. Thus, it is likely that a certain degree of vertical leakage (i.e., semiconfinement) exists in the hydrologic system at the site. It should be noted, however, that water level responses in adjacent test wells could be explained by improperly constructed borehole seals, and that characteristics of the TW-5, 7 data plots could be caused by factors other than leakage (e.g., hydrologic boundaries).

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		Checked by	Date
		Approved by	Sheet No. 1

F.2 Analysis of Multiple Borehole Production Well Test

The Soda Springs Plant derives its water supply from three high capacity production wells. In general, one of the plant wells is pumped continuously, one pumped intermittently, and one left idle to serve as backup. High capacity pumping of the plant wells results in a large scale perturbation to the ground water flow system. Analysis of this response can potentially provide large-scale hydraulic parameter values suitable for quantification of a site conceptual flow model.

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		Approved by	Sheet No. 2

On July 31, 1984, water level monitoring was conducted in plant production wells PW-1, PW-2, and PW-3 to determine if hydraulic responses due to pumping could be measured and analyzed. At that time, PW-3 was being pumped continuously, PW-2 was pumped intermittently, and PW-1 was idle. Water level measurements were taken with an electric probe and referenced to an arbitrary measuring point at each well.

Intermittent pumping at PW-2 was monitored for 45 minutes, during which, the pump was operated three times. The duration of pumping periods ranged from 6.13 to 6.23 minutes and duration of nonpumping periods ranged from 9.82 to 10.07 minutes. A chart recorder, installed by Monsanto to monitor pump operation, indicated that pump on/off sequences were very regular through time. PW-2 was equipped with a totalizing flow meter. Readings taken before and after each pumping period were used to calculate average flow rates. Flow rates during the three pumping periods ranged from 676 to 685 gpm, with a calculated average of 681 gpm. An attempt was made to measure water levels in PW-2. Unfortunately a layer of oil on top of the water column caused the electric probe to malfunction so that no measurements could be obtained.

Depth-to-water measurements were taken for about 50 minutes in PW-3, which according to Monsanto records, had been pumped continuously for many weeks. Since a flow meter was not installed on PW-3, average flow rates could not be calculated. As PW-3 pumped continuously, depth-to-water measurements were made at one minute intervals. Water levels were observed to fluctuate by about 0.3 feet, but the timing of fluctuations did not appear to correlate with the sequence of pumping in PW-2. It is probable that water level fluctuations were caused by small variations in the PW-3 pumping rate. Such variations could have been caused by power surges or changes in back-pressure within the discharge pipe.

PW-1 (located 611 feet from PW-2) was idle during the monitoring period. As a result, PW-1 could be used as an observation well to measure the hydraulic response resulting from pumping of the other two production wells. Water level monitoring was conducted in PW-1 for 40 minutes, with depth-to-water measurements taken at one minute intervals. Fortunately, a control signal in the PW-1 pump house indicated exactly when the PW-2 pump was turned on and off. These times were accurately recorded during water level monitoring at PW-1. A water level hydrograph for the PW-1 observation well is shown in Figure F-19. The shape of the hydrograph suggests a characteristic aquifer response due to intermittent pumping of PW-2.

Hydraulic response at PW-1, due to ~~intermittent~~ PW-2 pumping, was analyzed using standard aquifer test techniques. In order to apply these methods, it was assumed that the hydraulic response related to continuous pumping at PW-3 had achieved steady-state conditions. This assumption was reasonable, considering the length of time that PW-3 had been pumped prior to July 31st. A consequence of this assumption was that all water level changes in PW-1 could be attributed solely to the superimposed effects of pumping at PW-2. Pump test conditions are shown diagrammatically in Figure F-20. Hydraulic drawdown (s) was calculated assuming a static depth-to-water of 100.16 ft. This static level represents the position of the steady-state cone of depression due to pumping in PW-3.

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		Checked by	Date
		Approved by	Sheet No. 5

Theis Type-Curve Analysis Values of transmissivity and storativity were calculated based on the Theis (1935) type-curve method. To perform the analysis, a logarithmic plot of drawdown (s) vs. pumping time (t) was constructed, as shown in Figure F-21. To increase the number of ~~data~~ points, data from three pumping periods were included on the same plot. The resulting data plot was then superimposed on a Theis type-curve of the same scale. While keeping the coordinate axes parallel, the data plot was translated horizontally and vertically until the position of the Theis curve best fit the data. At any arbitrary match point, the following values were obtained:

$$W^*,\ u^*,\ s^*,\ t^*$$

where W^* and u^* are dimensionless parameters defining the type-curve and s^* and t^* were drawdown - time values obtained from the data plot. Transmissivity (T) was calculated using the following equation:

$$T = \frac{Q}{4\pi} \frac{W^*}{s^*} \qquad (3)$$

where

Q = pumping discharge rate (at PW-2)

For calculations performed herein a flow rate of 681 gpm was assumed. Storativity was calculated as follows:

$$S = \frac{4T}{r^2} t^* u^* \qquad (4)$$

where

r = radial distance from pumping to observation well (6.11 ft)

As shown in Figure F-21, two possible type-curve matches (A and B) were considered. It is felt that the range of transmissivity and storativity values obtained from the two matches served to bound the analysis.

Jacob Semilog and Theis Recovery Analyses A Jacob semilog plot and Theis recovery plot for production well test data are shown in Figures F-22 and F-23, respectively. Analysis of these plots for transmissivity is identical to the Jacob and Theis recovery methods described section F.1. As shown in Figure F-22, two straight line fits (A and B) were considered in the Jacob plot to bound the analysis.

Results Results for the multiple borehole production well test are summarized in Table F-3. Transmissivity values from the various analytical methods range from 1.7 to 3.0 $\times 10^5$ f^2/d and storativity from the Theis type-curve method ranges from 3.1 to 5.4 $\times 10^{-5}$. "Best guess" values are

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 7

$$T = 2.4 \times 10^{5}\ f^2/d$$

$$S = 4.3 \times 10^{-5}$$

The above values indicate a highly transmissive ground water flow system that is hydraulically "stiff". Although a phreatic surface exists in the hydrologic system, the low value of storativity suggests that either the system is highly confined or that ~~the~~ pumping periods were not of sufficient duration to experience delayed yield from the water table. Since other evidence suggests a certain degree of leakage in the hydrologic system, the later explanation is considered more plausible.

While transmissivity and storativity are related to characteristics of the horizontal flow system, analogous material properties are defined by hydraulic conductivity (K) and specific storage (S_s). For a horizontal flow system the following relationships hold:

$$K = \frac{T}{be} \qquad (5)$$

$$S_s = \frac{S}{be} \qquad (6)$$

where be is defined as the "effective" thickness of the system. In the basalt sequence at the site, horizontal ground water movement is controled primarily by flow in cinder zones.

Thus, for calculating hydraulic conductivity of cinder materials, a b value equal to the cumulative thickness of cinder zones should be utilized. For the 150 foot saturated sequence of basalts penetrated by the production wells, the total thickness of cinder zones might be expected to range from 10 to 50 feet. Substitution of these values into equation (5) gives the following estimated range of hydraulic conductivity in the cinder zones:

$$K = 4.8 \times 10^{3} \text{ to } 2.4 \times 10^{4} \text{ f/d}$$
$$(1.7 \text{ to } 8.5 \text{ cm/s})$$

Under confined conditions, water ~~[illegible]~~ is probably released from storage throughout the entire basalt sequence penetrated by the pumping well. Thus, for calculating specific storage, a b value equal to the total saturated thickness of 150 feet should be utilized. Substitution into equation (6) yields the following estimate of specific storage:

$$S_s = 2.9 \times 10^{-7} \text{ ft}^{-1} \; (9.4 \times 10^{-9} \text{ cm}^{-1})$$

Note that ~~the~~ above values are also given in metric units, since this is customary in many geotechnical disciplines.

Golder Associates	Subject MONSANTO	Made by T. Maurer	Job No. 843-1030
	FINAL REPORT	Checked by	Date 5/6/85
	ID	Approved by	Sheet No. 1 of 2

PRODUCTION WELL RESPONSES

Assumed Parameters

$$T = 2.4 \times 10^{5}\ f^2/d$$
$$S = 4.3 \times 10^{-5}$$

$$s = \frac{Q}{4\pi T} W(u)$$

$$u = \frac{Sr^2}{4Tt}$$

INTERMITTANT PUMPING OF PW-2 ON TW-25, 26, 27

$r = 990$ ft $\qquad Q = 681$ gpm
$t = 6.2$ min

$$s = \frac{(681\ g\,\cancel{min^{-1}})}{(4\pi)(2.4 \times 10^{5}\ \cancel{f^2 d^{-1}})}\left(\frac{f^3}{7.48\,g}\right)\left(\frac{1440\ \cancel{min}}{\cancel{d}}\right) W\left[\frac{(4.3 \times 10^{-5})(990\,f)^2}{(4)(2.4 \times 10^{5}\ f^2 d^{-1})(6.2\ \cancel{min})}\left(\frac{1440}{\cancel{d}}\right)\right]$$

$$\boxed{s = 0.17\ f}$$

INTERMITTANT PUMPING OF PW-1 ON TW-25, 26, 27

$r = 860$ f $\qquad Q = 980$ gpm (estimated)
$t = 4.3$ min

$$s = \frac{(980\ g\,\cancel{min^{-1}})}{(4\pi)(2.4 \times 10^{5}\ f^2 d^{-1})}\left(\frac{1 f^3}{7.48\,g}\right)\left(\frac{1440\ \cancel{min}}{\cancel{d}}\right) W\left[\frac{(4.3 \times 10^{-5})(860\,f)^2}{(4)(2.4 \times 10^{5}\ f^2 d^{-1})(4.3\ \cancel{min})}\left(\frac{1440\ \cancel{min}}{\cancel{d}}\right)\right]$$

$$\boxed{s = 0.25\ f}$$

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 2 of 2

CONCLUSIONS

If aquifer conditions existing in the vicinity of plant production wells were laterally continuous, measurable responses should have been observed at the TW-25, 26, 27 piezometer nest, caused by intermittent pumping of PW-2 or PW-1

Since measurable responses were not observed at these piezometers, it is concluded that system parameters (i.e., transmissivity, storativity) are not laterally uniform and/or a hydrologic boundary exists between the TW-25, 26, 27 cluster and the plant production wells.

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 1

F.3. TW-20 Multiple Borehole Test

As discussed in section F.1, while performing ~~during~~ short-term single borehole tests, measurable water level responses were observed in adjacent wells completed at different depths from the pumping wells. This was interpreted, at least qualitatively, to indicate the presence of a vertical hydraulic response through adjacent confining units. ~~in response to pumping.~~ In general, the single hole tests were of insufficient duration to allow for analysis of these responses.

At the TW-19, 20, 21, 34 well cluster, a longer term multiple borehole test was conducted in an attempt to better quantify the vertical hydraulic response resulting from pumping of a relatively transmissive cinder zone. TW-20 was pumped for 24 hours by continuous airlifting and during both pumping and recovery, water levels were monitored at TW-19 and TW-34 using Steven's recorders. Figure F-24 shows water level hydrographs for TW-19 and TW-34 during the test. At the end of 24 hours of pumping, both observation wells exhibited a drawdown of approximately 0.4 feet. Drawdown in the pumping well (TW-20)

~~the [illegible]~~ was probably on the order of 16 feet, representing ~~the~~ depth of the airline below the static water level. ~~in the [illegible]~~

Borehole locations and a generalized geologic section is shown in Figure F-25. The pumping well (TW-20) was apparently completed at the top of a thick cinder/vesicular zone, part of ~~[illegible]~~ which, is considered to comprise an aquifer. TW-34 was completed at the base of the cinder/vesicular zone, but since its hydraulic response was much less than TW-20, it must be assumed that one or more confining units of unknown thickness ~~must~~ exist within the parts of this unit. TW-19 was completed below the water table in dense basalt overlying the aquifer. The dense basalt ~~unit~~ is assumed to represent a confining unit (aquitard) within the layered system.

<u>RATIO METHOD ANALYSIS</u> Since the intent of the test was to measure vertical hydraulic conductivity of a confining unit, an analysis was performed based on the hydrologic response of TW-19. ~~which was completed in dense basalt assumed to represent an aquitard.~~ Under appropriate conditions, the Neuman and Witherspoon (1972) "ratio method"

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 3

provides an efficient analytical method for analyzing aquitard response. Assumptions of the ratio method are consistant with the aquifer/aquitard model depicted in Figure F-25. The method is based on early time piezometric data obtained before a significant hydraulic response has propogated to the top of the aquitard. Thus, the nature of the upper aquitard boundary (in this case, a phreatic surface) is of no consequence to the solution. The ratio method is valid provided that the following conditions are met:

$$\frac{r}{4}\sqrt{\frac{K'Ss'}{TS}} < 1.0 \qquad \text{Criteria A} \qquad (7)$$

$$t < \frac{0.1\,(b')^2}{D} \qquad \text{Criteria B} \qquad (8)$$

where

K' = vertical hydraulic conductivity of aquitard

Ss' = specific storage of aquitard

T = aquifer transmissivity

S = aquifer storativity

r = radial distance to observation well (20 ft)

t = pumping time

b' = aquitard thickness (16.5 ft)

$D = \frac{K'}{Ss'}$ = aquitard diffusivity

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 4

If criterion (A) and (B) are satisfied, the ratio of aquitard to aquifer drawdown, at a specified radial distance, is given by

$$\frac{s'}{s} = F[t_D, t_D'] \quad ; \text{ drawdown ratio} \qquad (9)$$

where

$$t_D = \frac{Tt}{Sr^2} \quad ; \text{ aquifer dimensionless time} \qquad (10)$$

$$t_D' = \frac{Dt}{z^2} \quad ; \text{ aquitard dimensionless time} \qquad (11)$$

s' = aquitard drawdown

s = aquifer drawdown

z = vertical distance of aquitard piezometer above aquifer/aquitard boundary

The function $F[t_D, t_D']$ is shown graphically in Figure F-26.

<u>Results</u> The ratio method generally assumes the existence of an aquifer piezometer at the same location as the aquitard piezometer. For the TW-20 pump test no such aquifer piezometer was available. Neuman and Witherspoon (1972) indicate that for a leaky, multiple aquifer system, the pumped aquifer response approaches the Theis (1935) equation at small radial distances from the pumping well. Thus, as a first approximation, aquifer response at the location of TW-19 was calculated using the Theis equation:

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 5

$$s = \frac{Q}{4\pi T} W(u) \qquad (12)$$

where

$$u = \frac{S r^2}{4Tt} \qquad (13)$$

with the following parameter values :

Q = 50 gpm

r = 20 ft

T = 800 ft^2/d

S = 3.7×10^{-6} aquifer

Discharge flow rate (Q) was estimated a number of times during the test by noting the time required to fill a container of known volume. Storage coefficient (S) was calculated assuming a specific storage of $3.05 \times 10^{-7} ft^{-1}$ ($10^{-8} cm^{-1}$) and an effective aquifer thickness of 12 feet. Transmissivity (T) represented a trial and error value which produced a reasonable drawdown at the pumping well ($r = 1$ foot) within the time frame of the test.

To perform the ratio test analysis, a logarithmic drawdown - time plot was constructed showing predicted aquifer response (r = 20 feet) and measured aquitard response at TW-19 as shown in Figure F-27. Early ~~data ...~~ TW-19 data points approached the detection limit of the Steven's recorder (0.01 feet) and were not considered

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 6

reliable. Thus, the early time aquitard response is extrapolated in Figure F-27 as a dashed line. For a chosen time, the following values were obtained from the data plot:

$$t^* = 100 \text{ min}$$

$$s' = .08 \text{ ft}$$

$$s = 10.8 \text{ ft}$$

The drawdown ratio was calculated using equation (9),

$$F = \frac{s'}{s} = 7.41 \times 10^{-3}$$

and aquifer dimensionless time was calculated using equation (10) in conjunction with the assumed aquifer parameter values,

$$t_D = \frac{T t^*}{S r^2} = 3.75 \times 10^4$$

Based on ratio method curves shown in Figure F-26, a value of aquitard dimensionless time was interpolated,

$$t_D' = 7.4 \times 10^{-2}$$

Solving equation (11) in terms of aquitard diffusivity,

$$D = \frac{t_D' z^2}{t^*} = 1.78 \times 10^{-3} \text{ f}^2/\text{s}$$

where z was taken as the distance from the base of the aquitard to the midpoint of the piezometer (12 feet).

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 7

Since diffusivity was equal to the ratio (K'/S_s'), an aquitard vertical hydraulic conductivity could be determined if specific storage was assumed. Based on a specific storage value of 3.05×10^{-7} ft^{-1} (10^{-8} cm^{-1}), the following conductivity was calculated:

.00379

$$K' = D\, S_s' = 5.4 \times 10^{-10} \text{ f/s } (1.7 \times 10^{-8} \text{ cm/s})$$

To verify that test conditions were appropriate for the ratio method, required parameter values were substituted into equations (7) and (8) to determine if criterion (A) and (B) were satisfied:

Criteria (A) : $3.5 \times 10^{-4} < 1.0$ (valid)

Criteria (B) : $t^* < 250$ min (valid)

Since the criterion were satisfied, it was concluded that test conditions were appropriate for application of the analytical method.

<u>Comments</u> A number of factors suggest that the calculated value of aquitard vertical hydraulic conductivity should be considere a lower-bound value. For example, water level response in an open standpipe piezometer (TW-19) may have been slower than the actual aquitard response due to the effects of wellbore storage. If significant "log time" occurred, the ratio method would tend

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 8

to underestimate aquitard hydraulic conductivity. Furthermore, TW-19 was completed within a locally transmissive layer within the aquitard, which would have had the effect of reducing drawdown at the measurement point compared to that predicted by the analytical model. Application of the ratio method in this situation would also lead to an underestimate in aquitard hydraulic conductivity.

¶ It should also be pointed out that the ratio test measures only aquitard hydraulic conductivity in ~~the~~ immediate vicinity of the piezometer installation. Since this represents a small-scale measurement, ratio test results can not be applied to the confining unit on a larger scale, which might be more appropriate for quantification of a site conceptual model. Thus, the calculated value of hydraulic conductivity should be considered a lower bound value for dense basalt, but not for the confining unit as a whole.

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No.

For the ratio test to be applicable, an observation piezometer must be completed within a confining layer above or below the pumped aquifer. If rock logged as "fresh gray basalt" is assumed to represent confining materials, this condition is satisfied by TW-19 (see Figure F-25). Since TW-34 is completed in transmissive materials that may comprise the lower part of an aquifer, the ratio method is not considered valid for analysis of hydraulic response measured in this piezometer.

Golder Associates	Subject: Monsanto Final Report ID	Made by: [signature]	Job No. 843-K30
		Checked by	Date 5/6/85
		Approved by	Sheet No. 1 OF 2

RADIUS OF INFLUENCE OF TW-20 TEST

$$s = \frac{Q}{4\pi T}\, W(u)$$

where $u = \dfrac{Sr^2}{4Tt}$

$s = 0.03$ ft　　　$r = ?$ (f)

$Q = 50$ gpm　　　$t = 24$ hr

$T = 800\ f^2/d$

$S = 3.7 \times 10^{-6}$

$$s = \frac{(50\ g\ \cancel{min^{-1}})}{(4\pi)(800\ f^2\ \cancel{d^{-1}})}\,[W(u)]\left(\frac{1f^3}{7.48\ g}\right)\left(\frac{60\ \cancel{min}}{\cancel{1hr}}\right)\left(\frac{24\ \cancel{hr}}{\cancel{1d}}\right)$$

$$\boxed{s = 9.575 \times 10^{-1}\ f\quad W(u)}$$　　[STO ϕ1]

$$u = \frac{(3.7 \times 10^{-6})(r\ f)^2}{(4)(800\ f^2\ \cancel{d^{-1}})(\cancel{24hr})}\left(\frac{\cancel{24hr}}{\cancel{d}}\right)$$

$$\boxed{u = 1.156 \times 10^{-9}\left(\frac{r}{f}\right)^2}$$　　[STO ϕ2]

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 2 of 2

TRIAL AND ERROR SOLUTION

r (ft)	u ( )	W(u) ( )	s (ft)
1	1.156×10^{-9}	20.001	19.2
10	1.156×10^{-7}	15.396	14.7
100	1.156×10^{-5}	10.791	10.3
200	4.625×10^{-5}	9.404	9.0
300	1.041×10^{-4}	8.593	8.2
500	2.891×10^{-4}	7.572	7.3
→ 1000	1.156×10^{-3}	6.187	5.9
2000	4.625×10^{-3}	4.804	4.6
3000	1.041×10^{-2}	3.999	3.8
5000	2.891×10^{-2}	2.995	2.9
10000	1.156×10^{-1}	1.693	1.6

CHECK WITH JACOB APPROXIMATION

$$s = \frac{Q}{4\pi T} \ln 2.246 \frac{Tt}{Sr^2}$$

$$r = 1000 \text{ f}$$

$$s = \frac{(50 \text{ g min}^{-1})}{(4\pi)(800 \text{ f}^2 \text{ d}^{-1})}\left(\frac{\text{ft}^3}{7.48 \text{ g}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right) \ln\left[\frac{2.246\,(800 \text{ f}^2 \text{ d}^{-1})(24 \text{ hr})\left(\frac{1 \text{ d}}{24 \text{ hr}}\right)}{(3.7 \times 10^{-6})(1000 \text{ f})^2}\right]$$

$$s = 5.9 \text{ f}$$

CONCLUSIONS

If aquifer conditions at the TW-20 test site were laterally extensive, a measurable response should have been observed in nearby test wells

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No.

TABLE F-1 RESULTS OF SINGLE BOREHOLE CONSTANT DISCHARGE PUMP TESTS.

BOREHOLE	Q (gpm)	S_{max} (ft)	t_{max} (min)	T (ft^2/d)	METHOD	S'_{max} (ft)
TW-3	12.68 12.88 12.83	— .68 —	— 63 —	2350 1630 1730	J (early) J (late) TR	— .53 (TW-4) —
TW-5	10.49 10.49	43.45 —	70 —	14.3 10.7	J TR	.01 (TW-6) —
TW-6	9.34 9.34	.39 —	68 —	8670 9690	J TR	.02 (TW-5) —
TW-7	7.17 7.17	1.33 —	73 —	477 538	J TR	.07 (TW-8) —
TW-10	15.0 15.0	1.13 —	39 —	2650 2250	J TR	.05 (TW7) —

NOTES

Q = average flow rate during pumping period
S_{max} = maximum drawdown in pumping well
t_{max} = maximum pumping time
T = calculated transmissivity
S'_{max} = maximum drawdown in adjacent test well

(1) : Water levels not measured in adjacent well

J : Jacob semilog analysis (Cooper and Jacob, 1946)
TR : Theis recovery analysis (Theis, 1935)

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
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TABLE F-2 RESULTS OF SINGLE BOREHOLE SLUG TESTS

BOREHOLE	Smax (ft)	T (f^2/d)	METHOD	S'max (ft)
TW-4	108	11.1	MH	.08 (TW-3)
TW-8	75	.52	MH	(1)
TW-9	39	6.9	MH	(1)

NOTES

Smax = maximum drawdown in pumping well
T = calculated transmissivity
S'max = maximum drawdown in adjacent test well

(1) : Water levels not measured in adjacent well

MH : modified Hvorslev analysis (Hvorslev, 1951)

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No.

TABLE F-3. RESULTS OF MULTIPLE BOREHOLE PRODUCTION WELL TEST

CALCULATED TRANSMISSIVITY (f^2/d)	CALCULATED STORATIVITY ( )	METHOD
2.3×10^5	3.1×10^{-5}	TC (A)
1.7×10^5	5.4×10^{-5}	TC (B)
2.1×10^5	—	J (A)
2.7×10^5	—	J (B)
3.0×10^5	—	TR

NOTES

TC : Theis type-curve method (Theis, 1935)

J : Jacob semilog method (Cooper and Jacob, 1946)

TR : Theis recovery method (Theis, 1935)

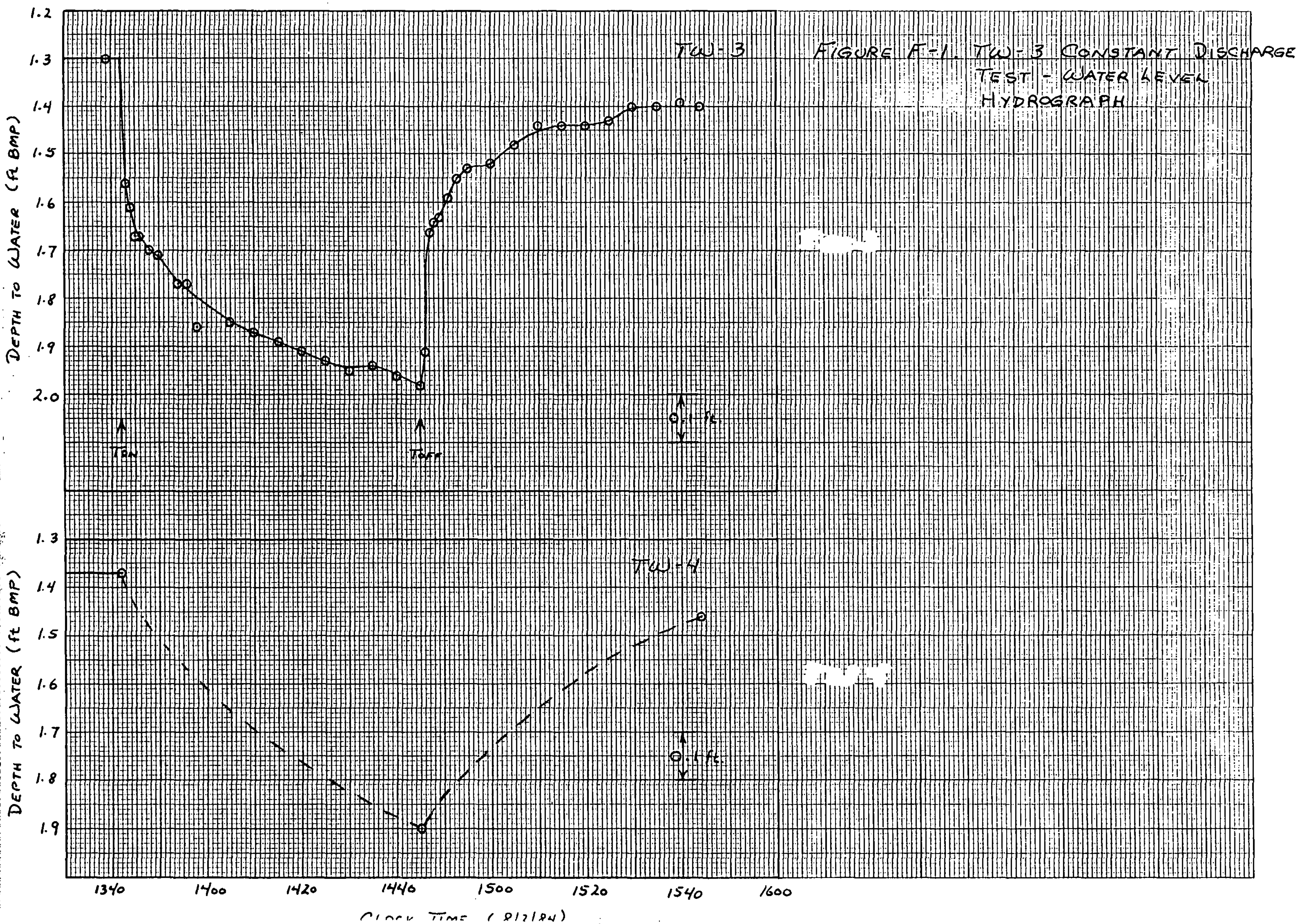

FIGURE F-1. TW-3 CONSTANT DISCHARGE TEST - WATER LEVEL HYDROGRAPH

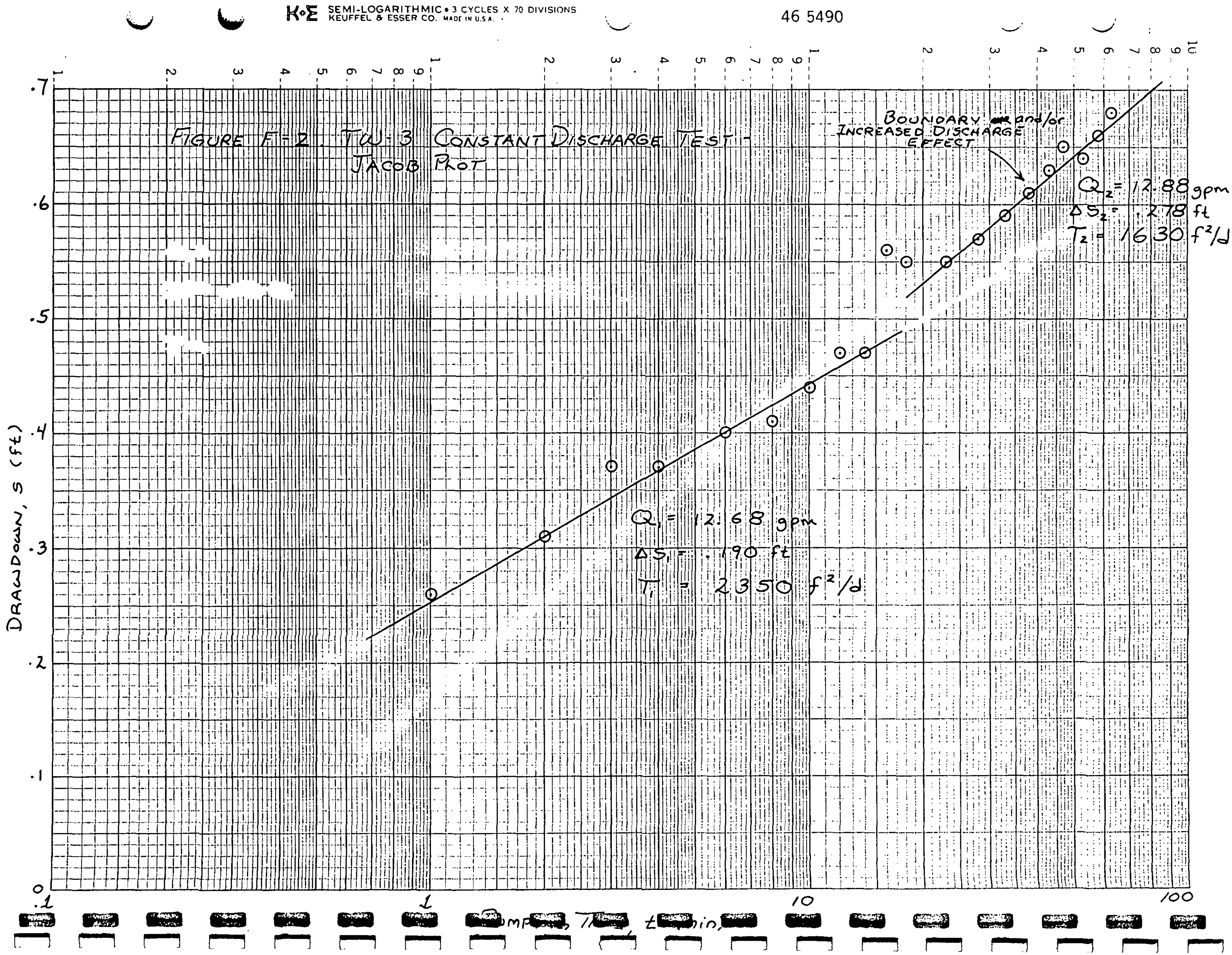
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FIGURE F-2. TW-3 CONSTANT DISCHARGE TEST -
JACOB PLOT
BOUNDARY and/or
INCREASED DISCHARGE
EFFECT
Q2 = 12.88 gpm
ΔS2 = .278 ft
T2 = 1630 f²/d
Q1 = 12.68 gpm
ΔS1 = .190 ft
T1 = 2350 f²/d
DRAWDOWN, s (ft)
.7
.6
.5
.4
.3
.2
.1
0
.1
1
10
100

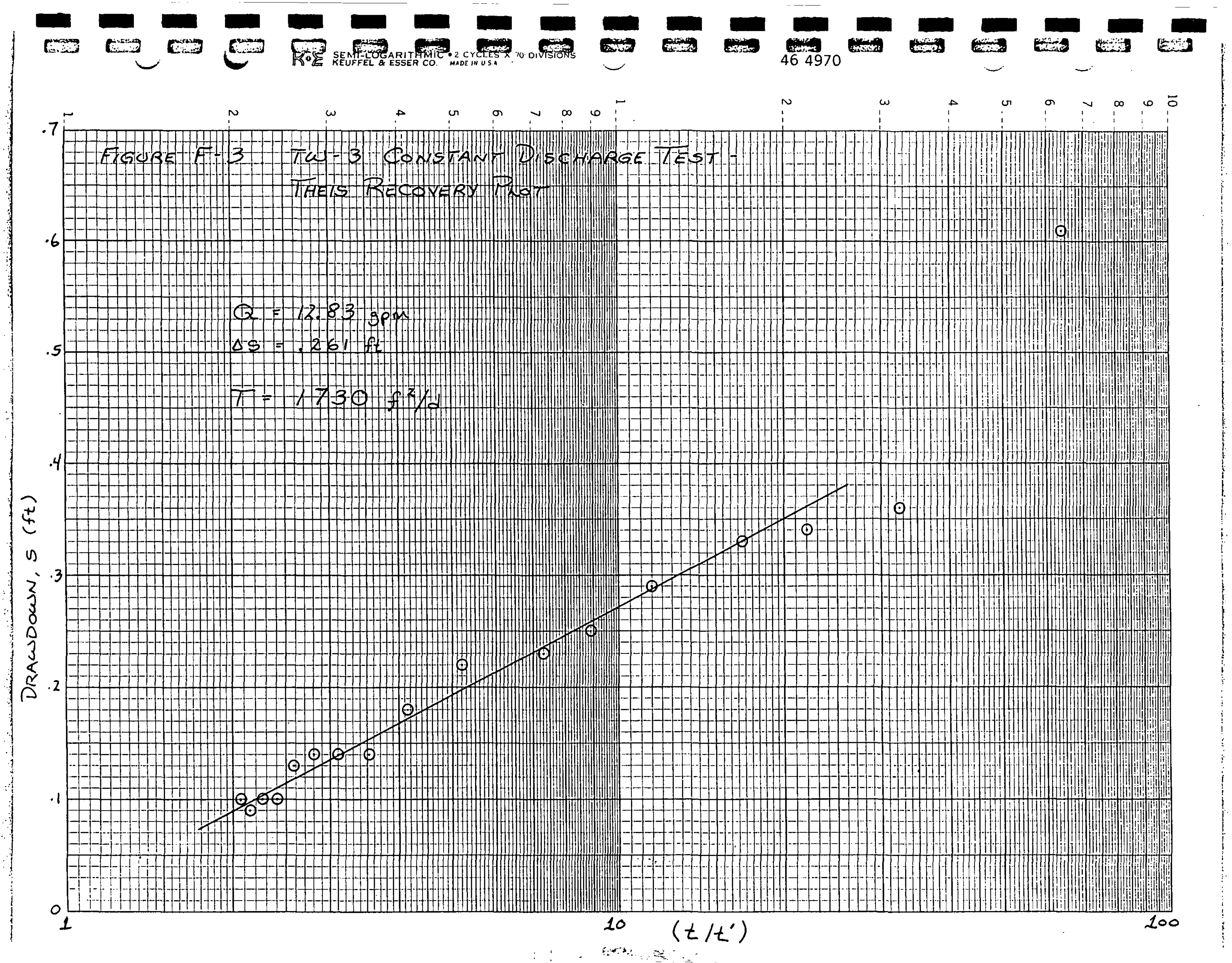

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FIGURE F-3 TW-3 CONSTANT DISCHARGE TEST - THEIS RECOVERY PLOT
Q = 12.83 gpm
ΔS = .261 ft
T = 1730 ft²/d
DRAWDOWN, S (ft)
(t/t')

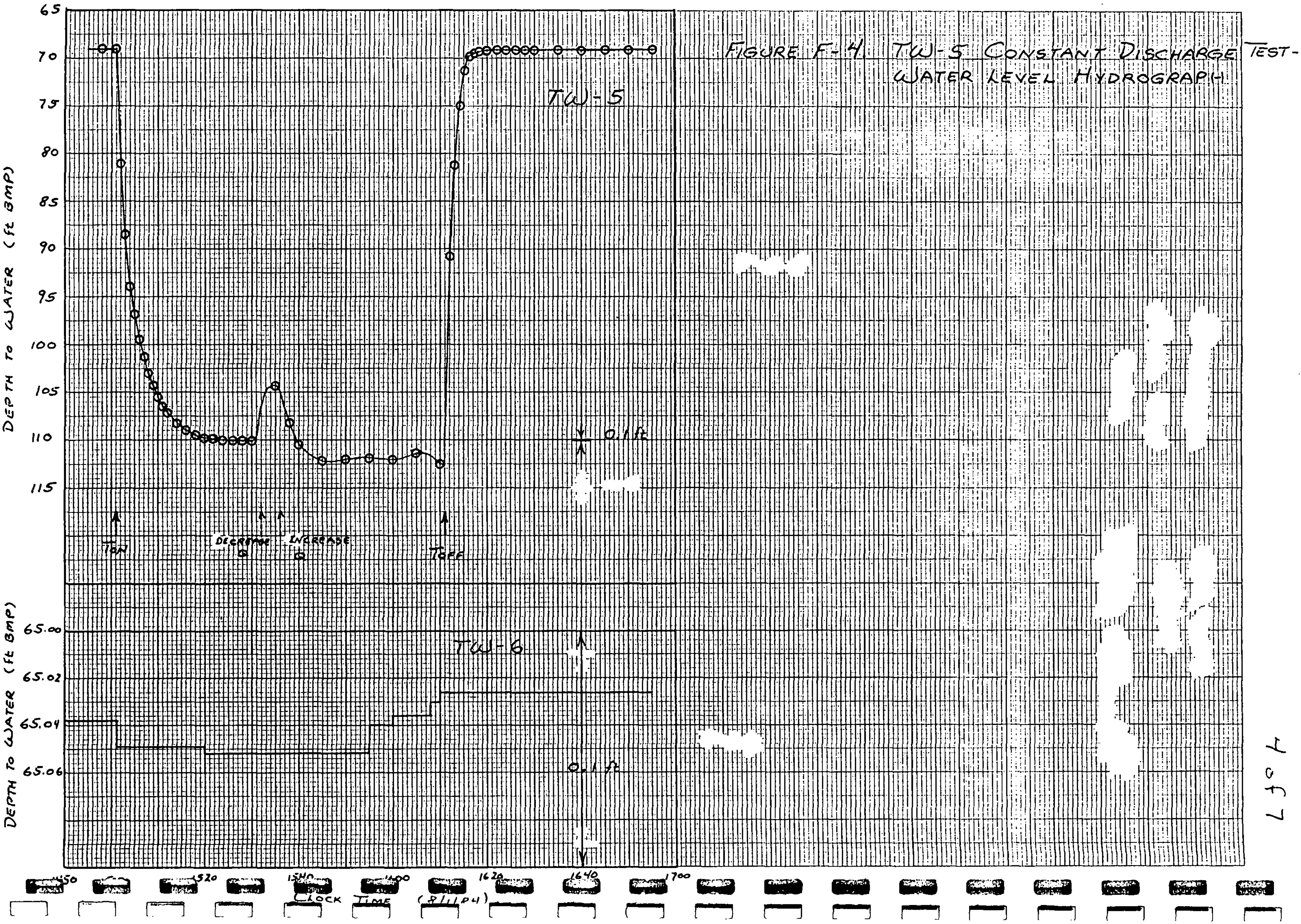

FIGURE F-4 TW-5 CONSTANT DISCHARGE TEST - WATER LEVEL HYDROGRAPH

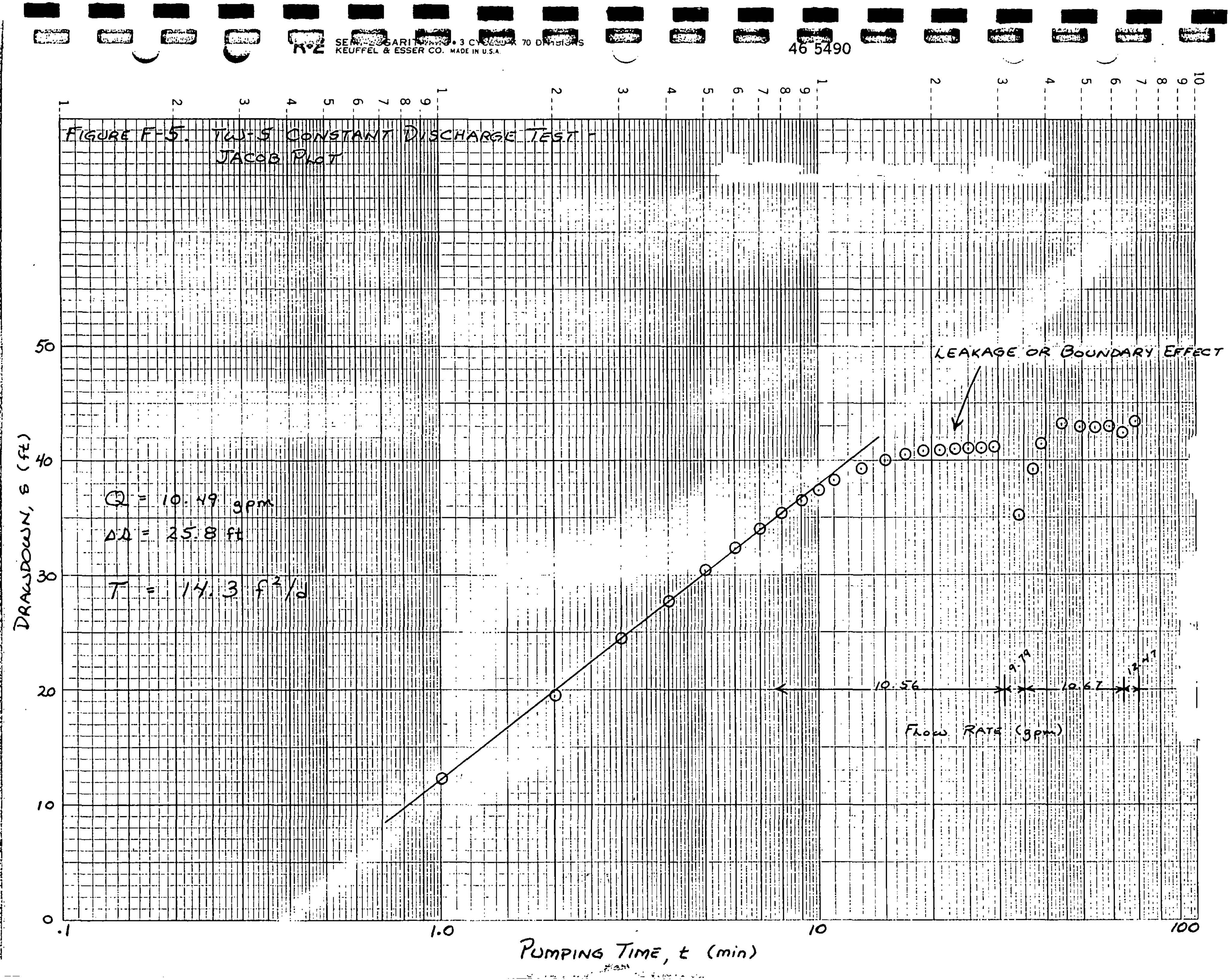

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FIGURE F-5. TW-5 CONSTANT DISCHARGE TEST - JACOB PLOT
LEAKAGE OR BOUNDARY EFFECT
Q = 10.49 gpm
Δs = 25.8 ft
T = 14.3 ft²/d
10.56
9.79
10.67
12.47
FLOW RATE (gpm)
DRAWDOWN, s (ft)
PUMPING TIME, t (min)
0
10
20
30
40
50
.1
1.0
10
100

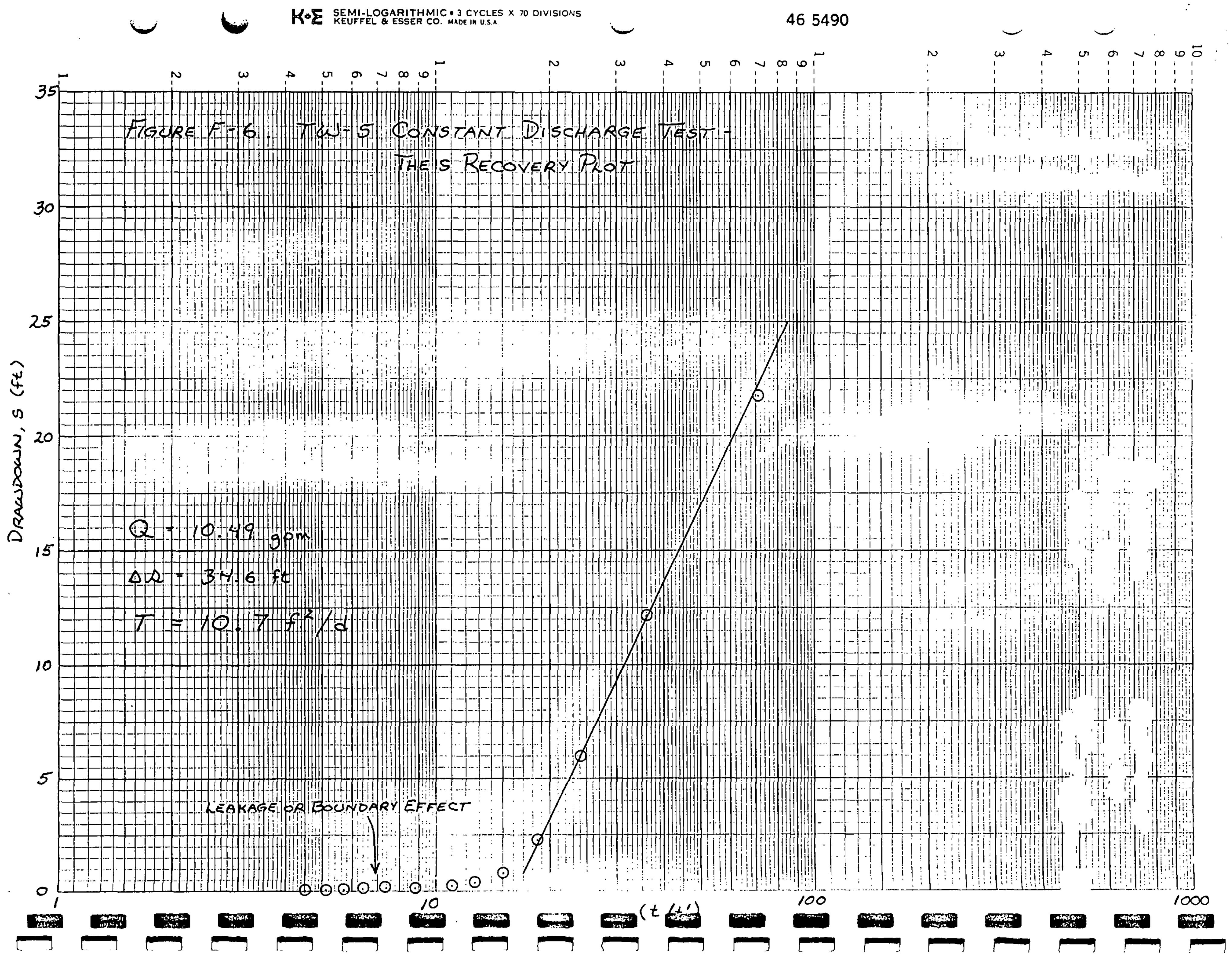
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FIGURE F-6. TW-5 CONSTANT DISCHARGE TEST -
THEIS RECOVERY PLOT
Q = 10.49 gpm
ΔΔ = 34.6 ft
T = 10.7 f²/d
LEAKAGE OR BOUNDARY EFFECT
DRAWDOWN, s (ft)
(t/t')
35
30
25
20
15
10
5
0
1
10
100
1000

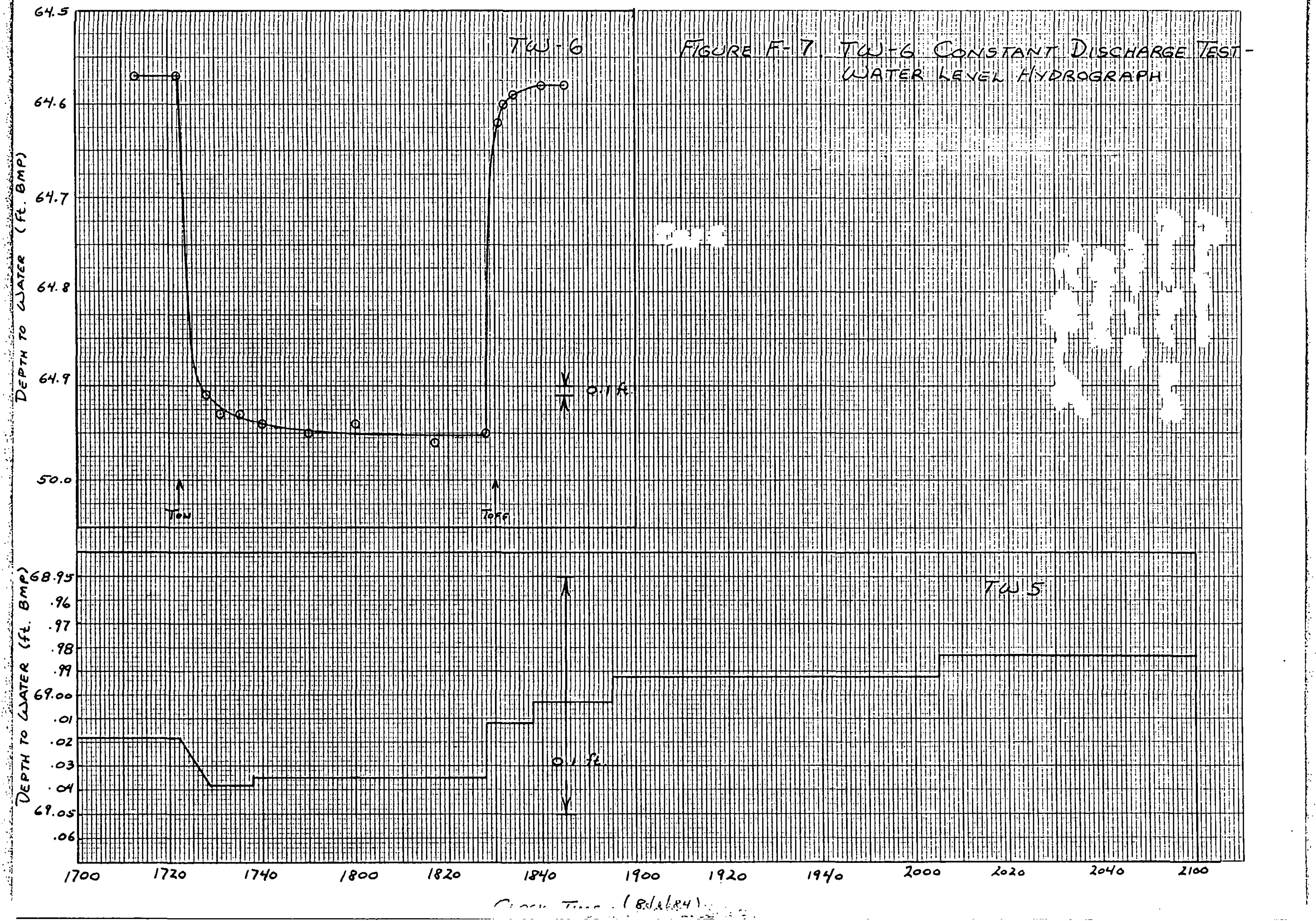


FIGURE F-7. TW-6 CONSTANT DISCHARGE TEST - WATER LEVEL HYDROGRAPH

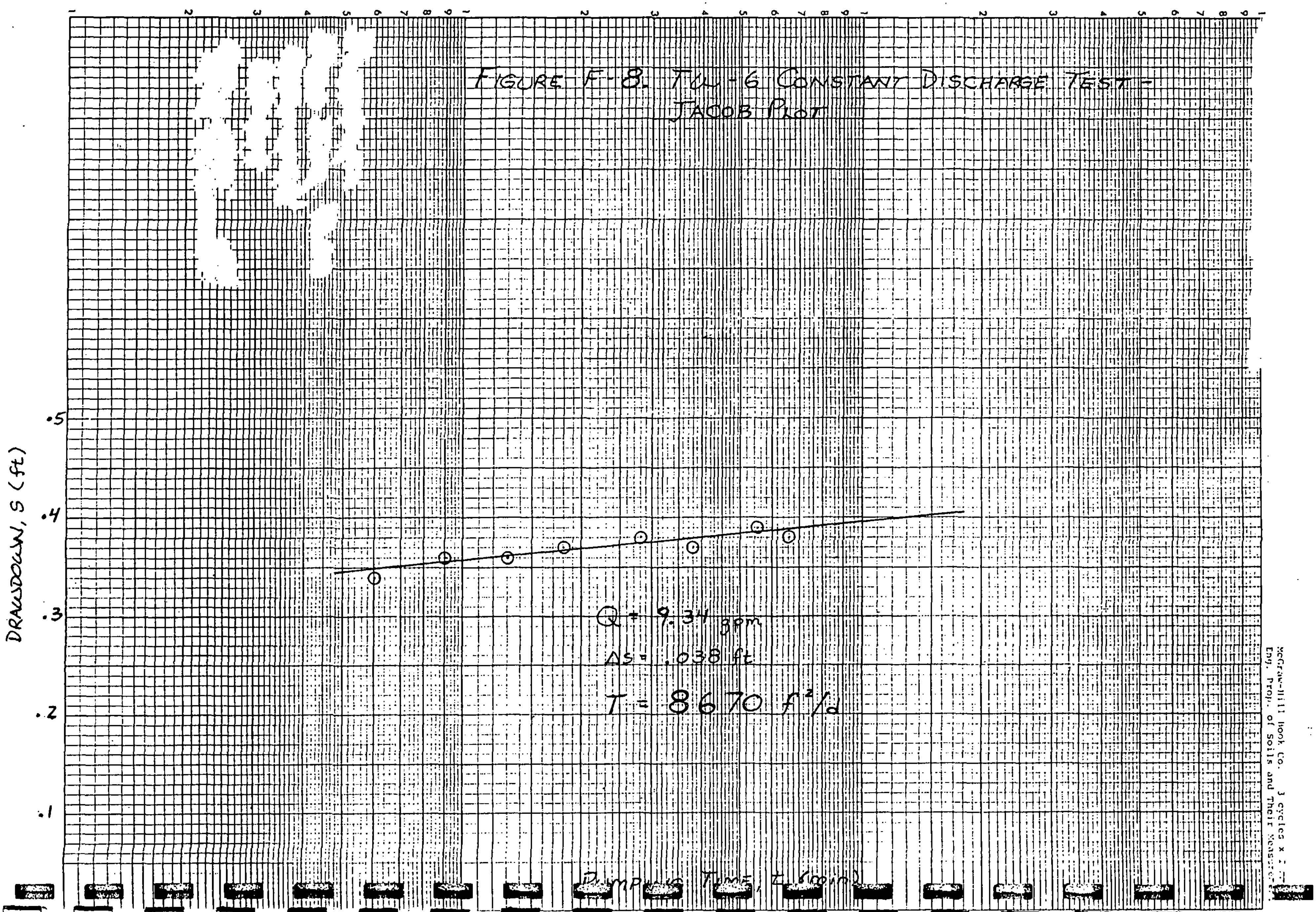


FIGURE F-8. TW-6 CONSTANT DISCHARGE TEST - JACOB PLOT

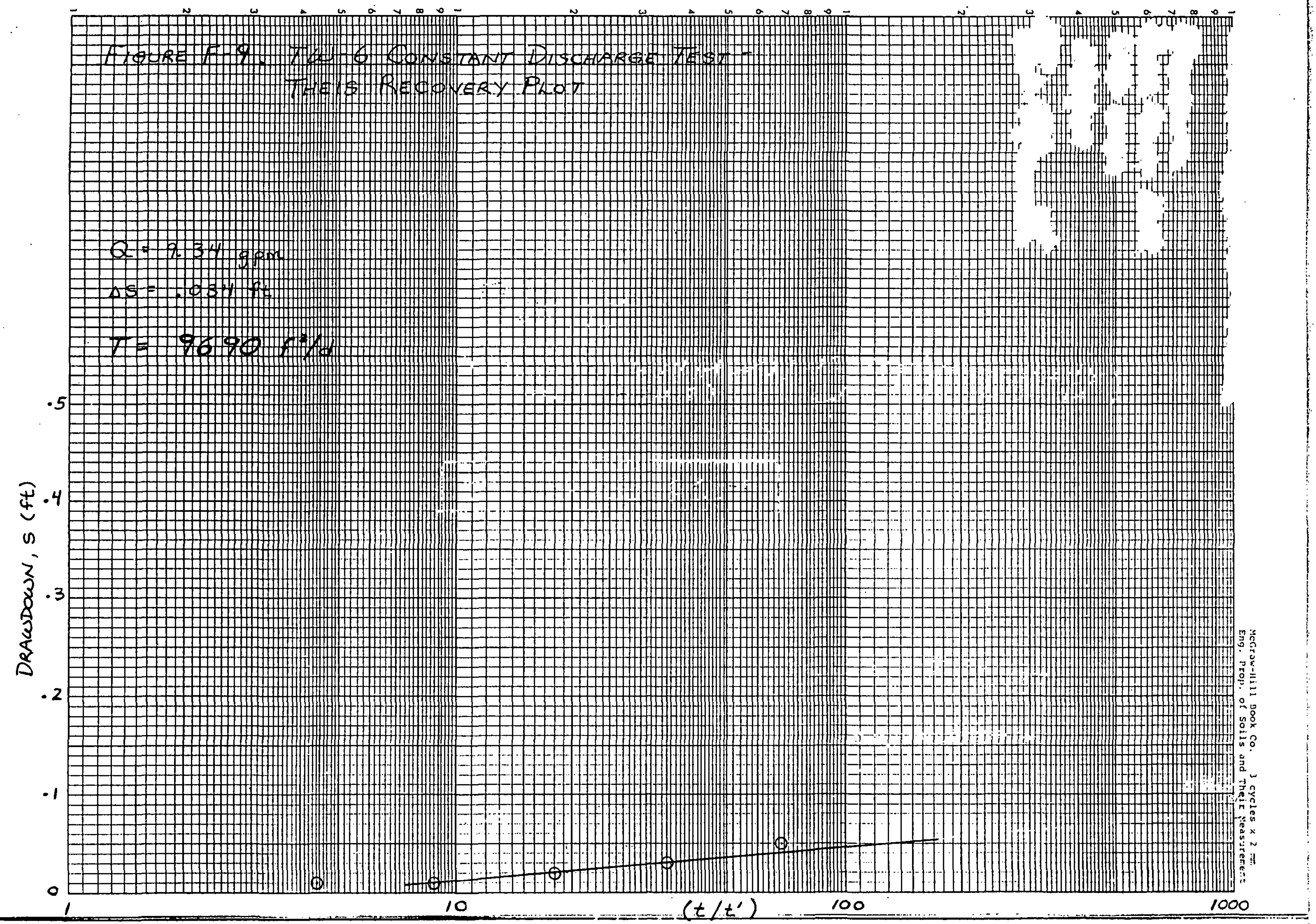


FIGURE F-9. TW-6 CONSTANT DISCHARGE TEST - THEIS RECOVERY PLOT
Q = 9.34 gpm
ΔS = .034 ft
T = 9690 ft²/d
DRAWDOWN, s (ft)
.5
.4
.3
.2
.1
0
1
10
(t/t')
100
1000
McGraw-Hill Book Co. 3 cycles x 2 mm
Eng. Prop. of Soils and Their Measurement

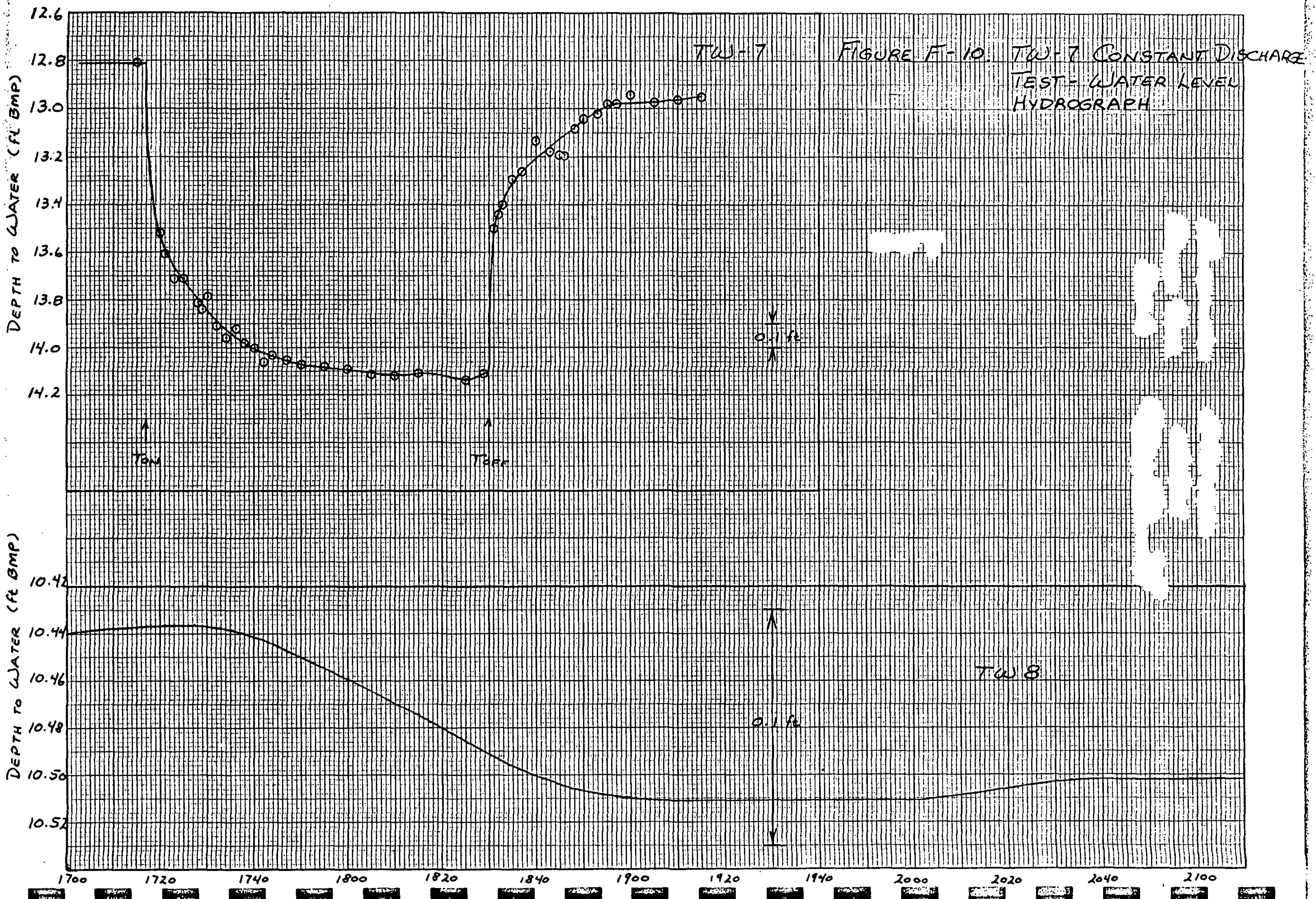
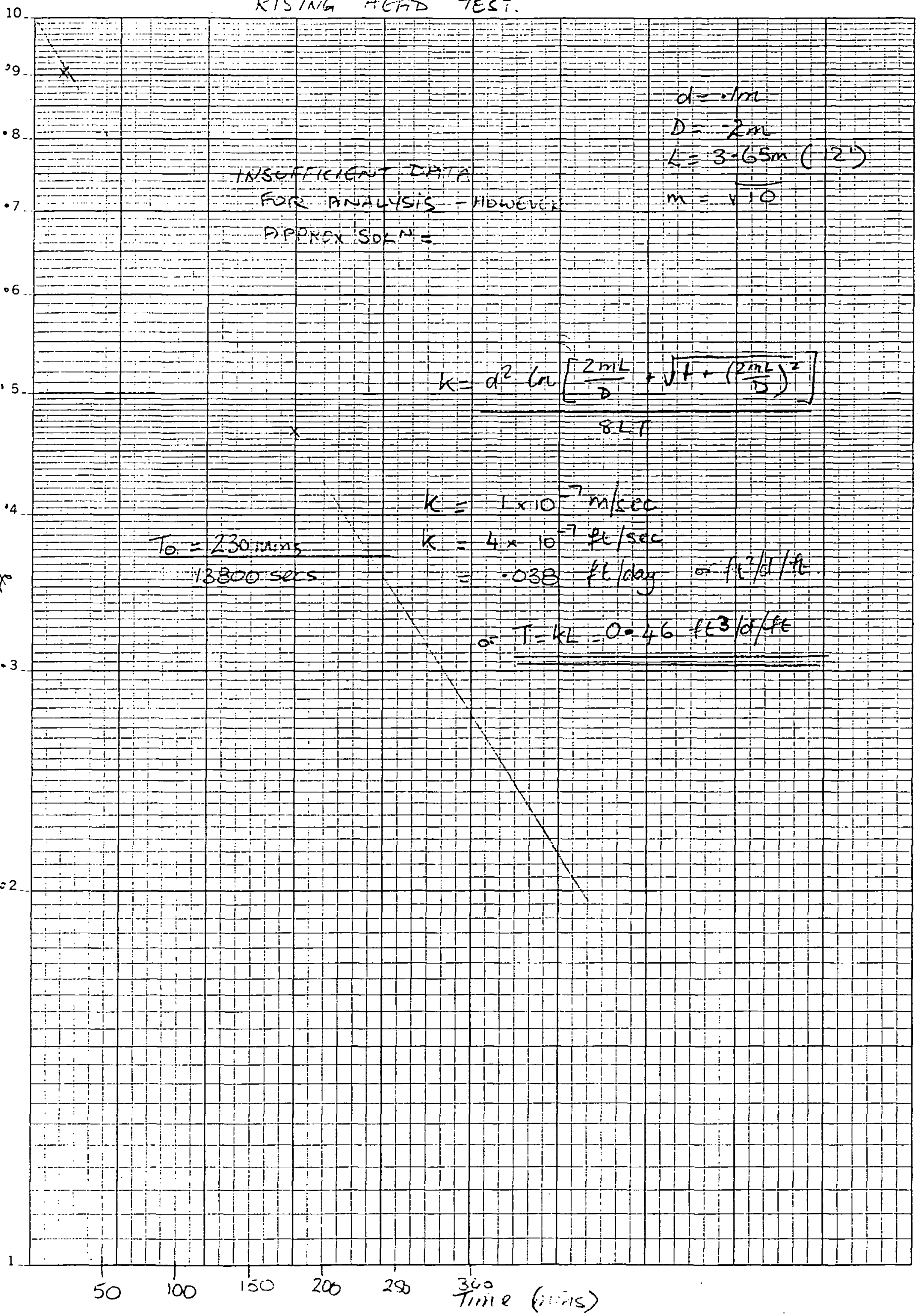


FIGURE F-10. TW-7 CONSTANT DISCHARGE TEST - WATER LEVEL HYDROGRAPH

842-1543

T1025

RISING HEAD TEST.



$d = \cdot 1m$

$D = \cdot 2m$

$L = 3\cdot 65m$ (12')

$m = \sqrt{10}$

INSUFFICIENT DATA FOR ANALYSIS - HOWEVER APPROX SOLN =

$$k = \frac{d^2 \ln\left[\frac{2mL}{D} + \sqrt{1 + \left(\frac{2mL}{D}\right)^2}\right]}{8LT}$$

$T_0 = 230$ mins
13800 secs

$K = 1 \times 10^{-7}$ m/sec

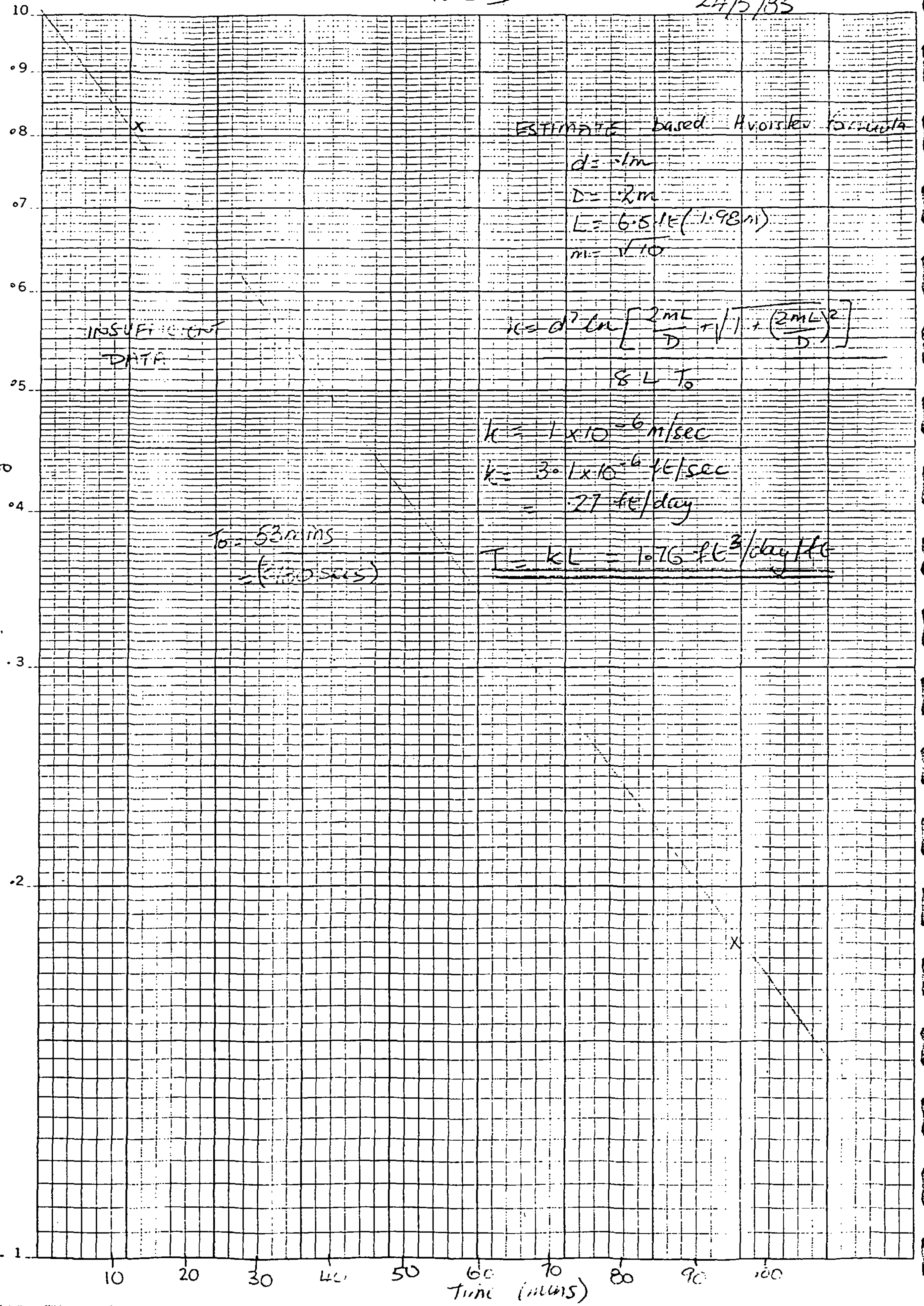
$k = 4 \times 10^{-7}$ ft/sec

$= \cdot 038$ ft/day or ft²/d/ft

or $T = kL = 0\cdot 46$ ft³/d/ft

TW2 1

842 1543
24/5/85



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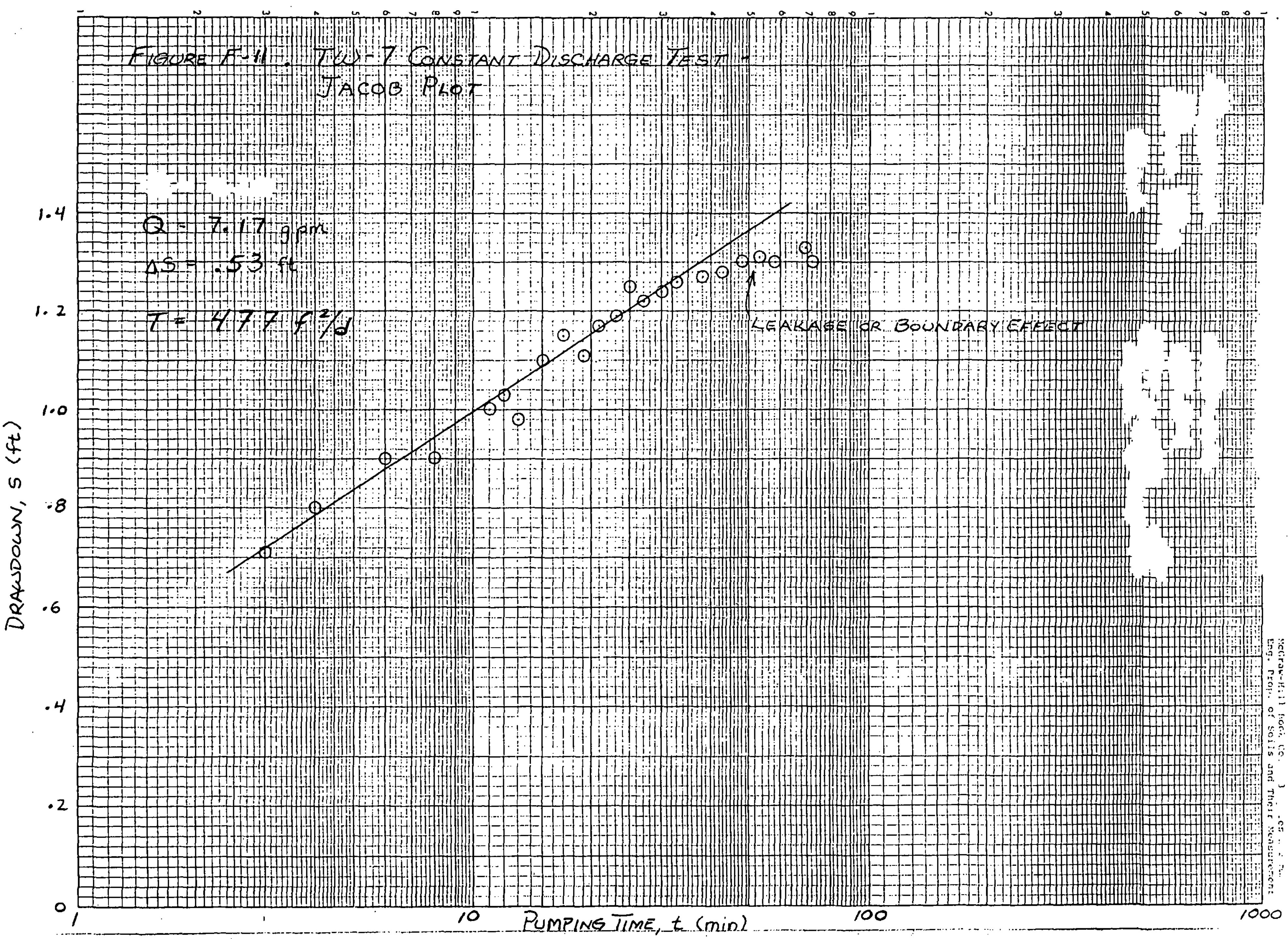


FIGURE F-11. TW-7 CONSTANT DISCHARGE TEST - JACOB PLOT
Q = 7.17 gpm
ΔS = .53 ft
T = 477 f²/d
LEAKAGE OR BOUNDARY EFFECT
DRAWDOWN, S (ft)
PUMPING TIME, t (min)
1.4
1.2
1.0
.8
.6
.4
.2
0
1
10
100
1000

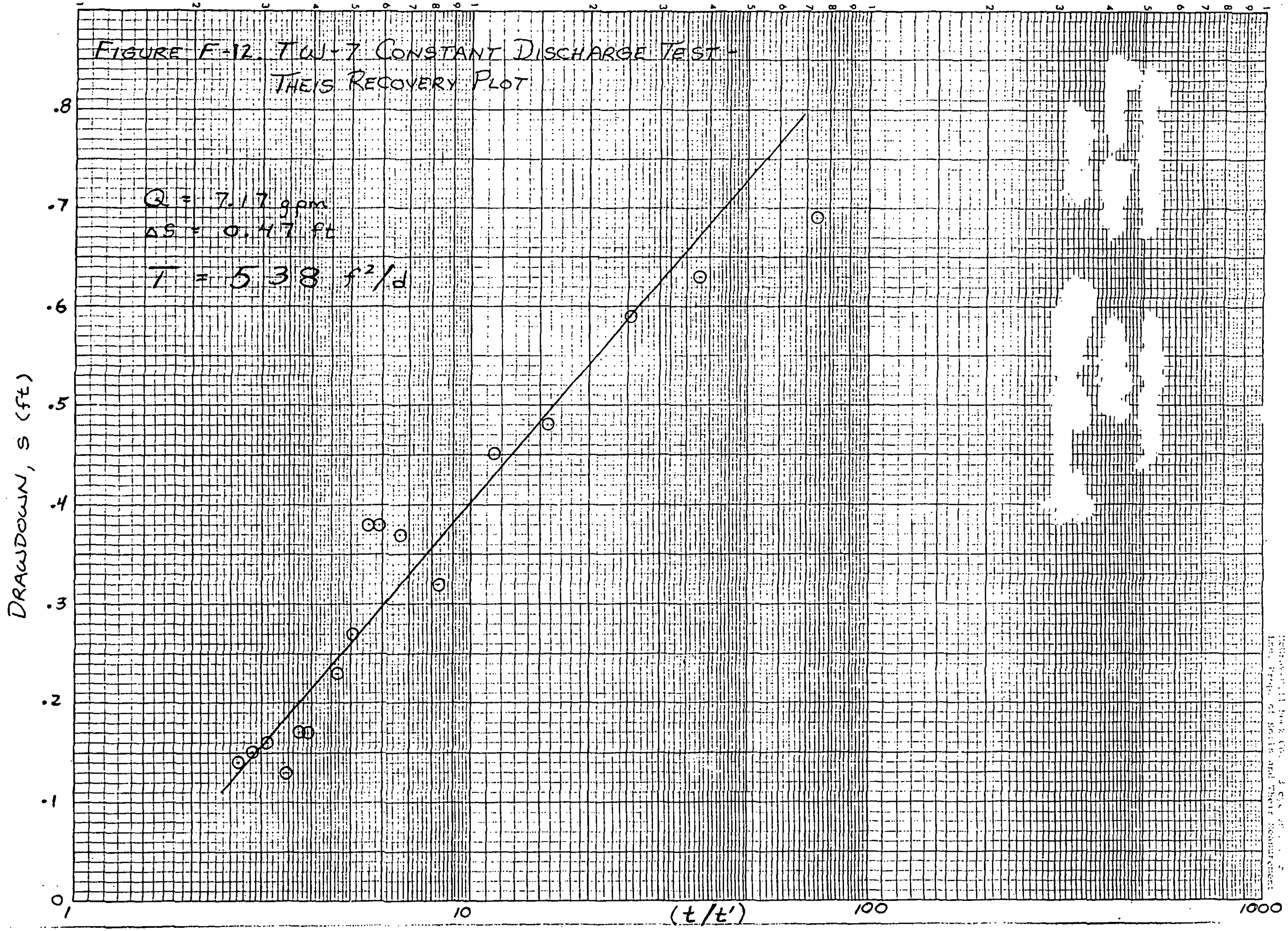
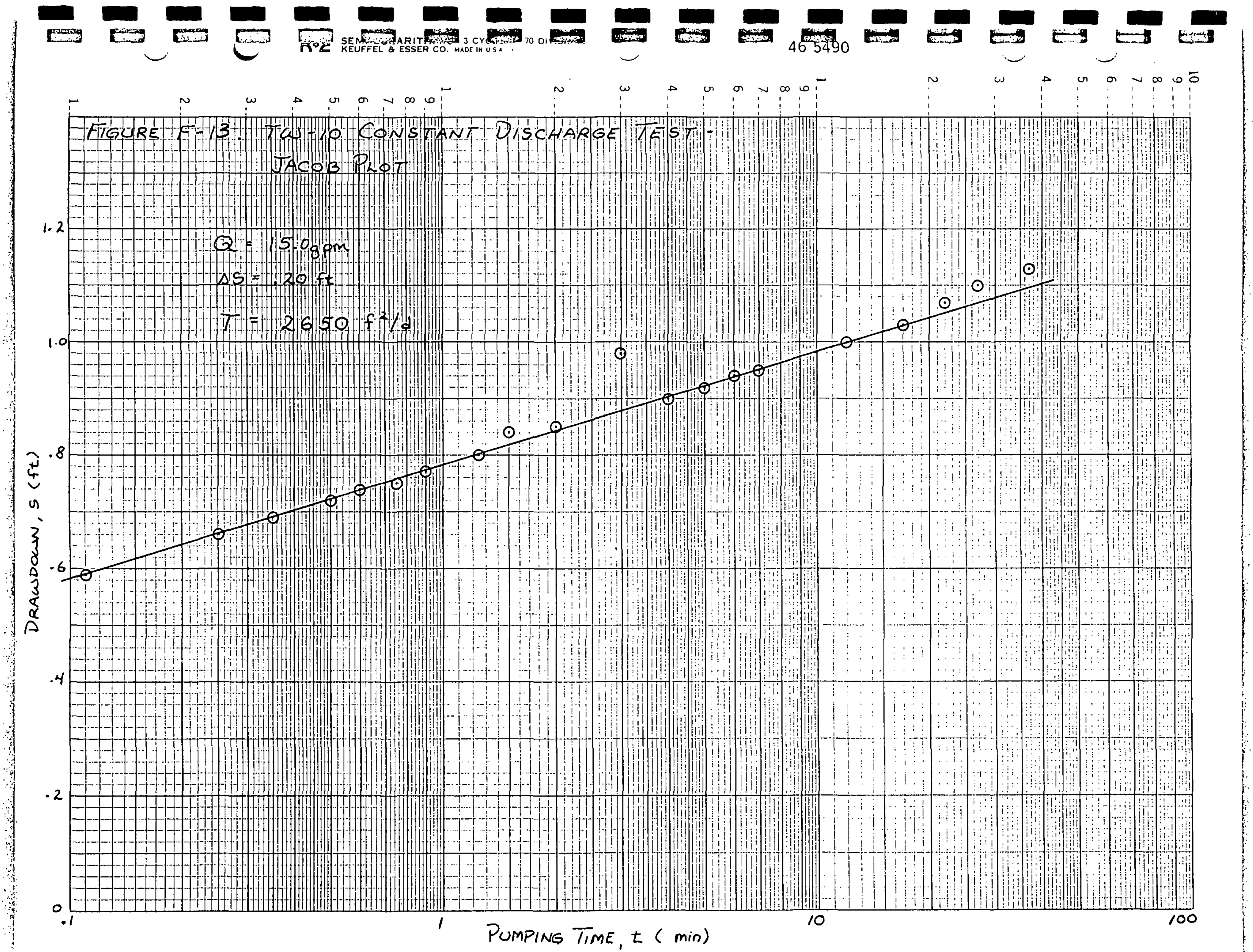


FIGURE F-12. TW-7 CONSTANT DISCHARGE TEST -
THEIS RECOVERY PLOT
Q = 7.17 gpm
ΔS = 0.47 ft
T = 538 f²/d
DRAWDOWN, S (ft)
.8
.7
.6
.5
.4
.3
.2
.1
0
1
10
100
1000
(t/t')



SEMI-LOGARITHMIC 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 5490
FIGURE F-13. TW-10 CONSTANT DISCHARGE TEST -
JACOB PLOT
Q = 15.0 gpm
ΔS = .20 ft
T = 2650 f²/d
DRAWDOWN, s (ft)
1.2
1.0
.8
.6
.4
.2
0
.1
1
10
100
PUMPING TIME, t (min)

46 4970

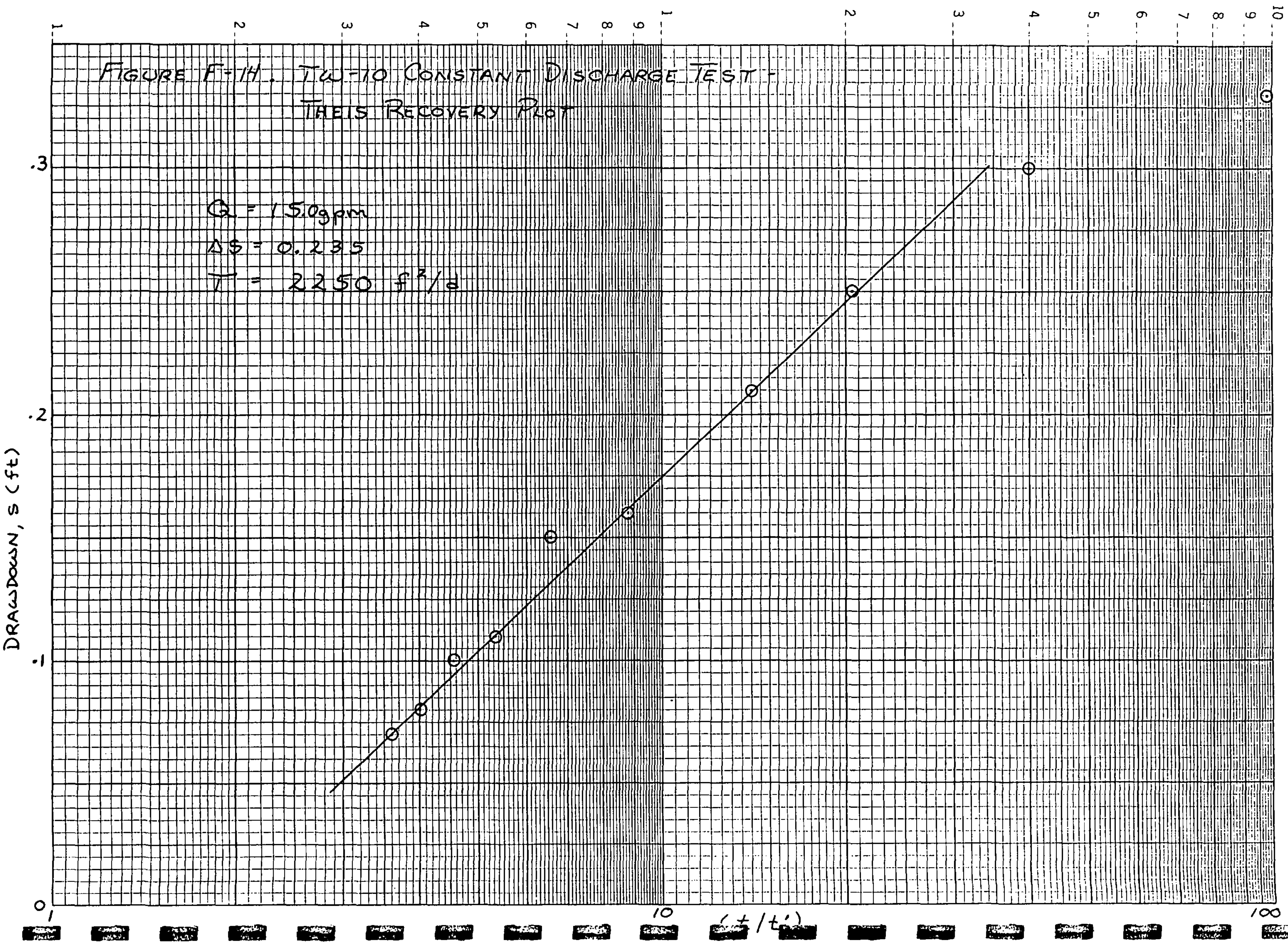


FIGURE F-14. TW-10 CONSTANT DISCHARGE TEST - THEIS RECOVERY PLOT

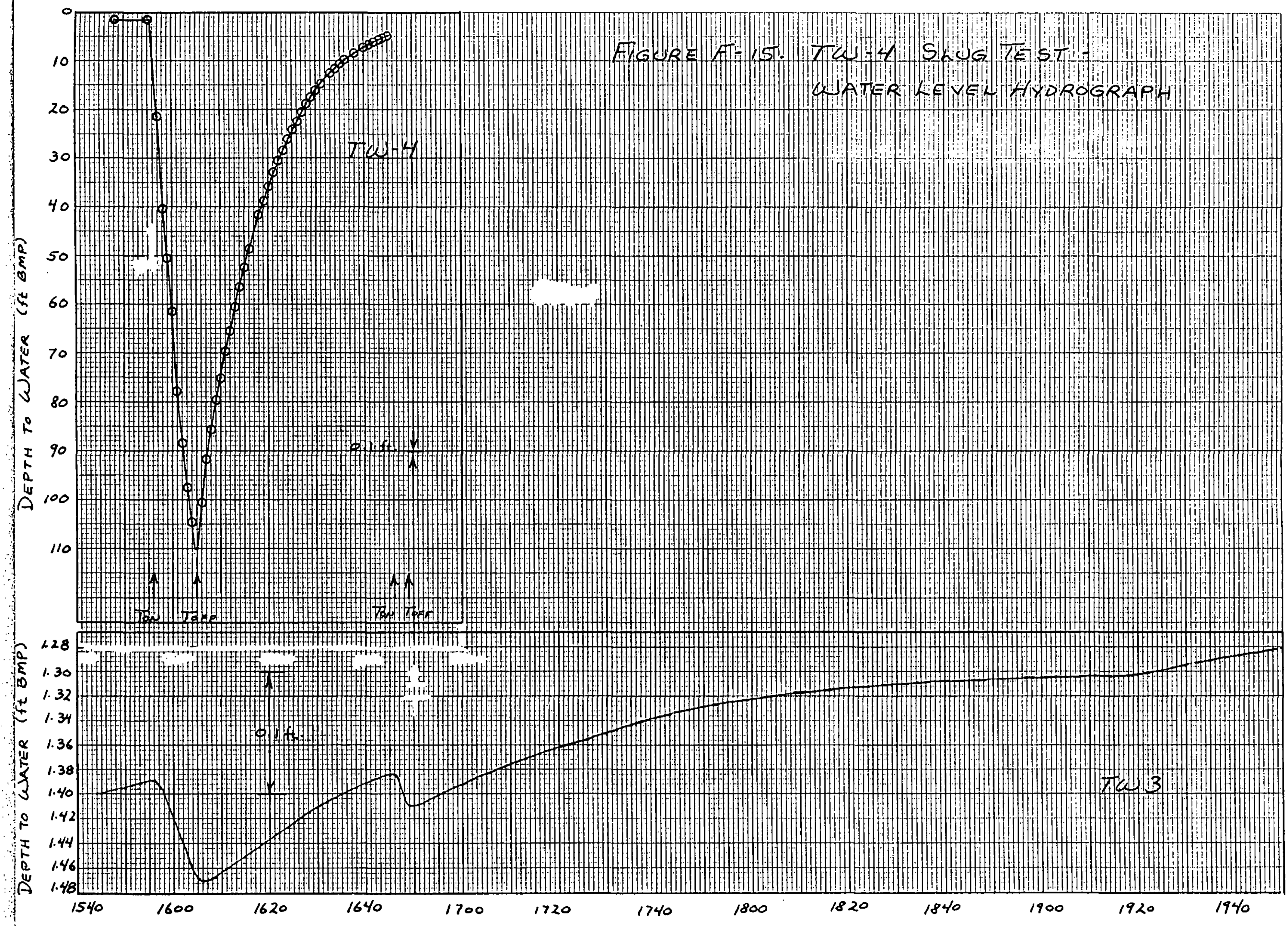


FIGURE F-15. TW-4 SLUG TEST - WATER LEVEL HYDROGRAPH

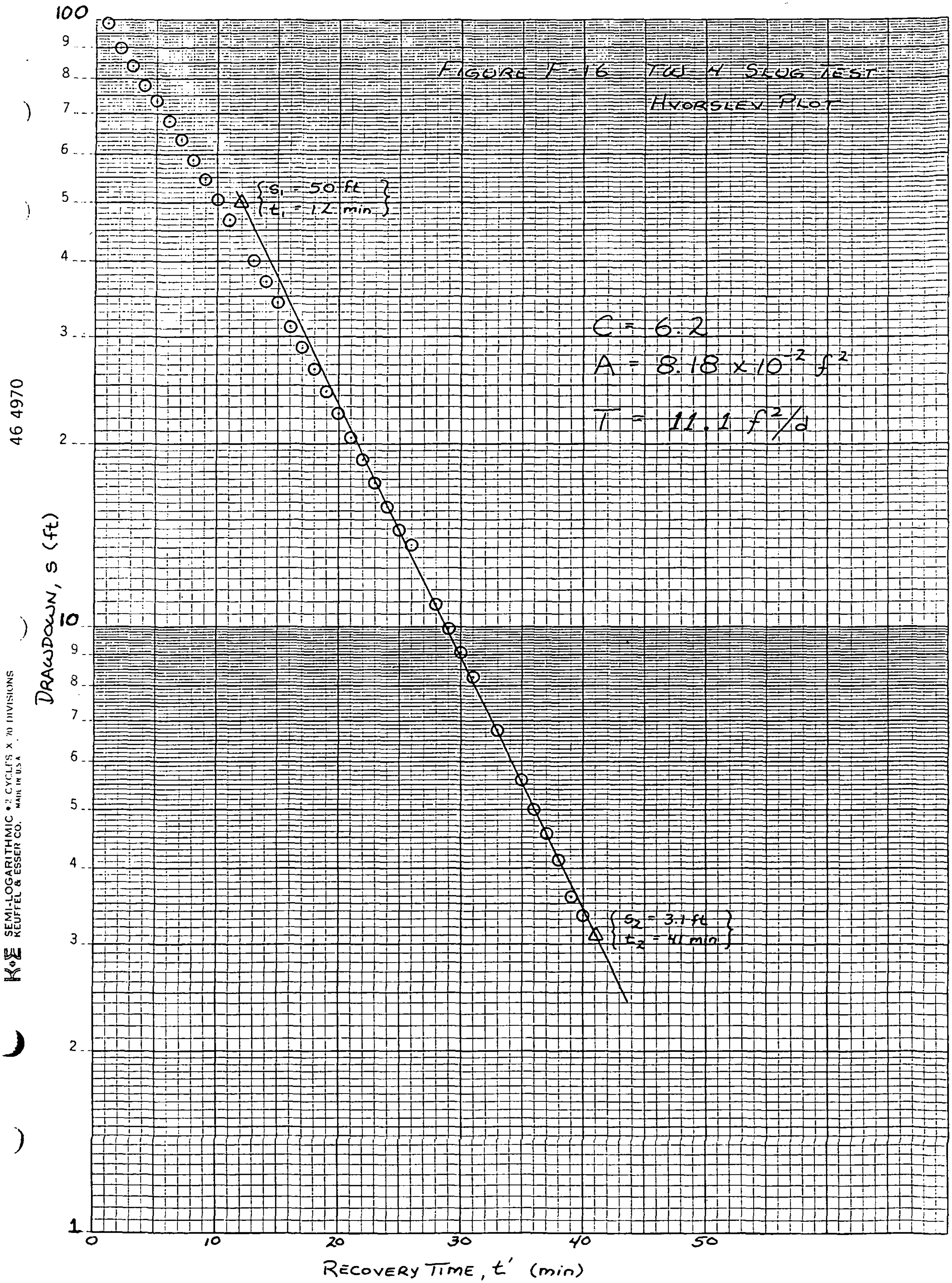


FIGURE F-16 TW-4 SLUG TEST
HVORSLEV PLOT
s1 = 5.0 ft
t1 = 12 min
s2 = 3.1 ft
t2 = 41 min
C = 6.2
A = 8.18 x 10^-2 f^2
T = 11.1 f^2/d
DRAWDOWN, s (ft)
RECOVERY TIME, t' (min)
100
10
1
0
10
20
30
40
50
46 4970
K&E SEMI-LOGARITHMIC • 2 CYCLES x 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

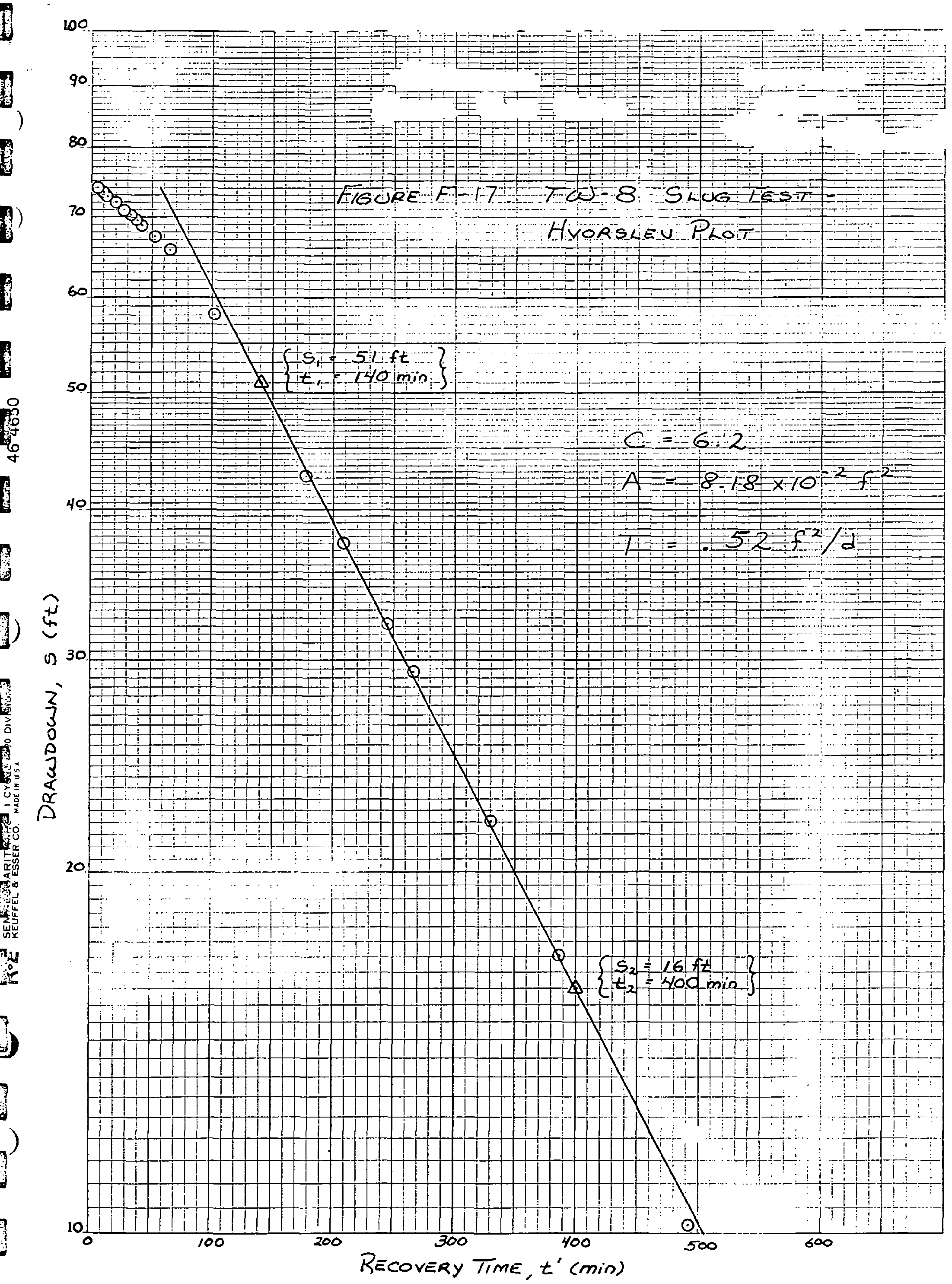
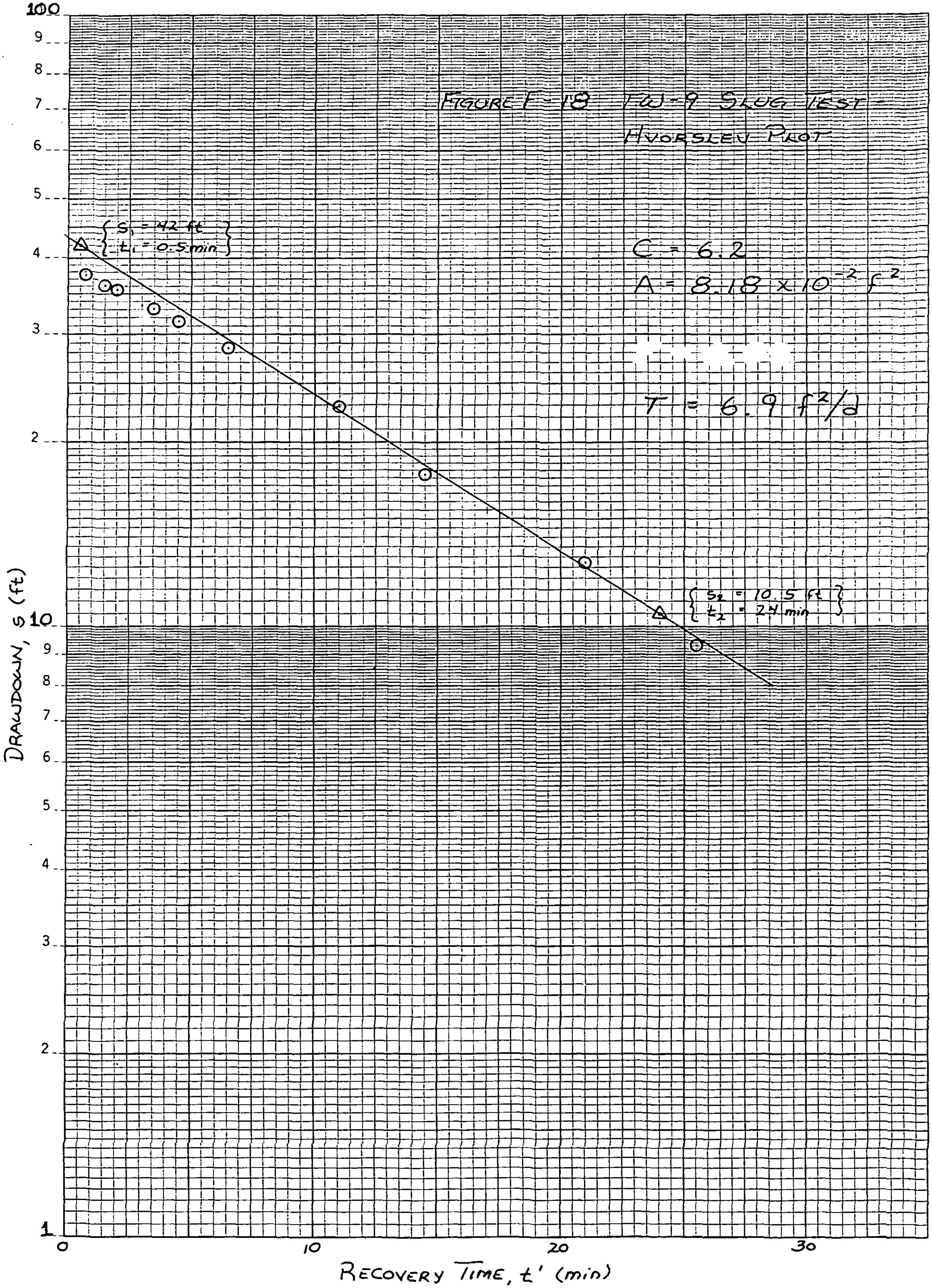
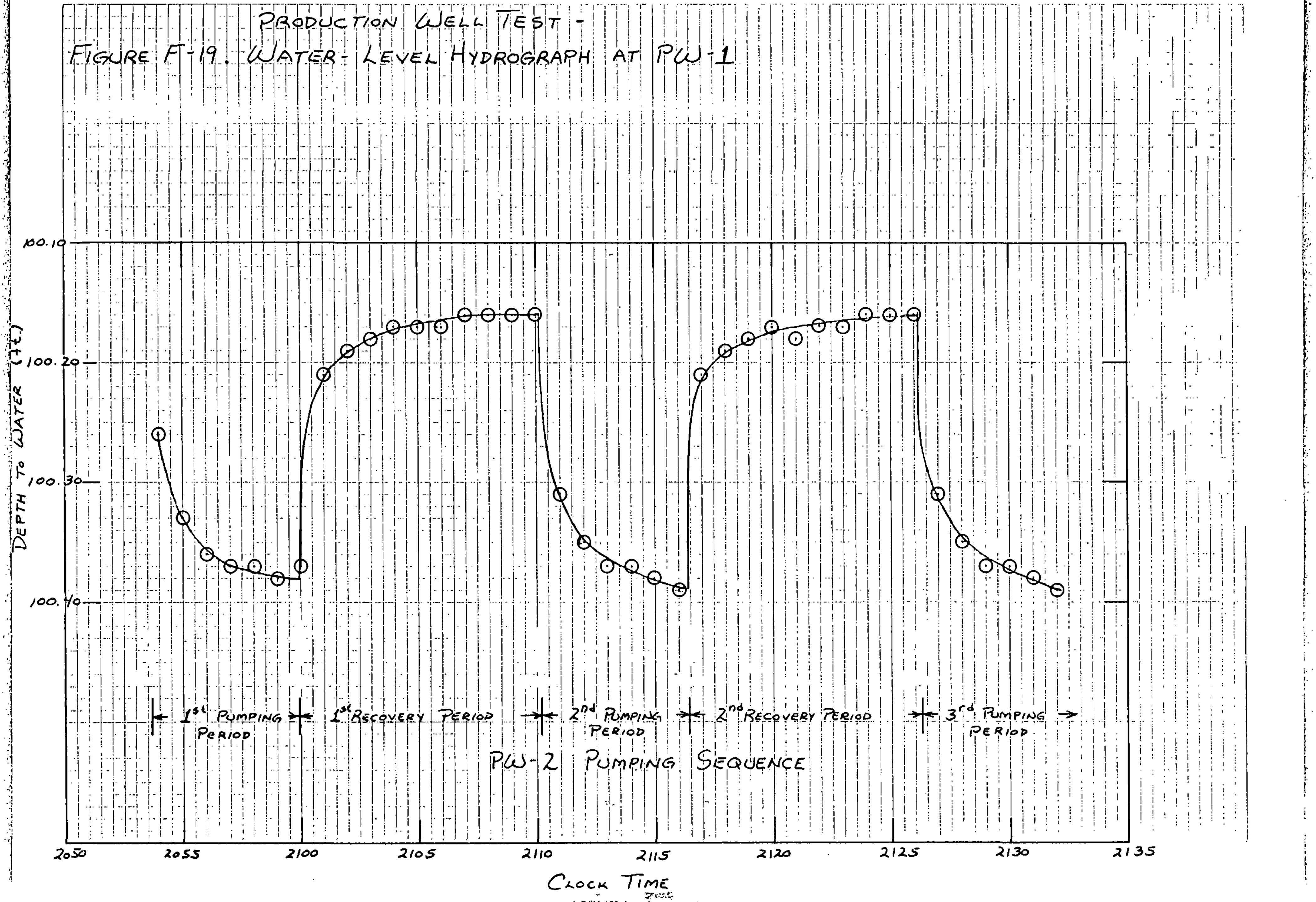


FIGURE F-17. TW-8 SLUG TEST - HVORSLEV PLOT
S1 = 51 ft
t1 = 140 min
S2 = 16 ft
t2 = 400 min
C = 6.2
A = 8.18 x 10^-2 f^2
T = .52 f^2/d
DRAWDOWN, s (ft)
RECOVERY TIME, t' (min)
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
46 4630
SEMI-LOGARITHMIC 1 CYCLE
KEUFFEL & ESSER CO. MADE IN USA

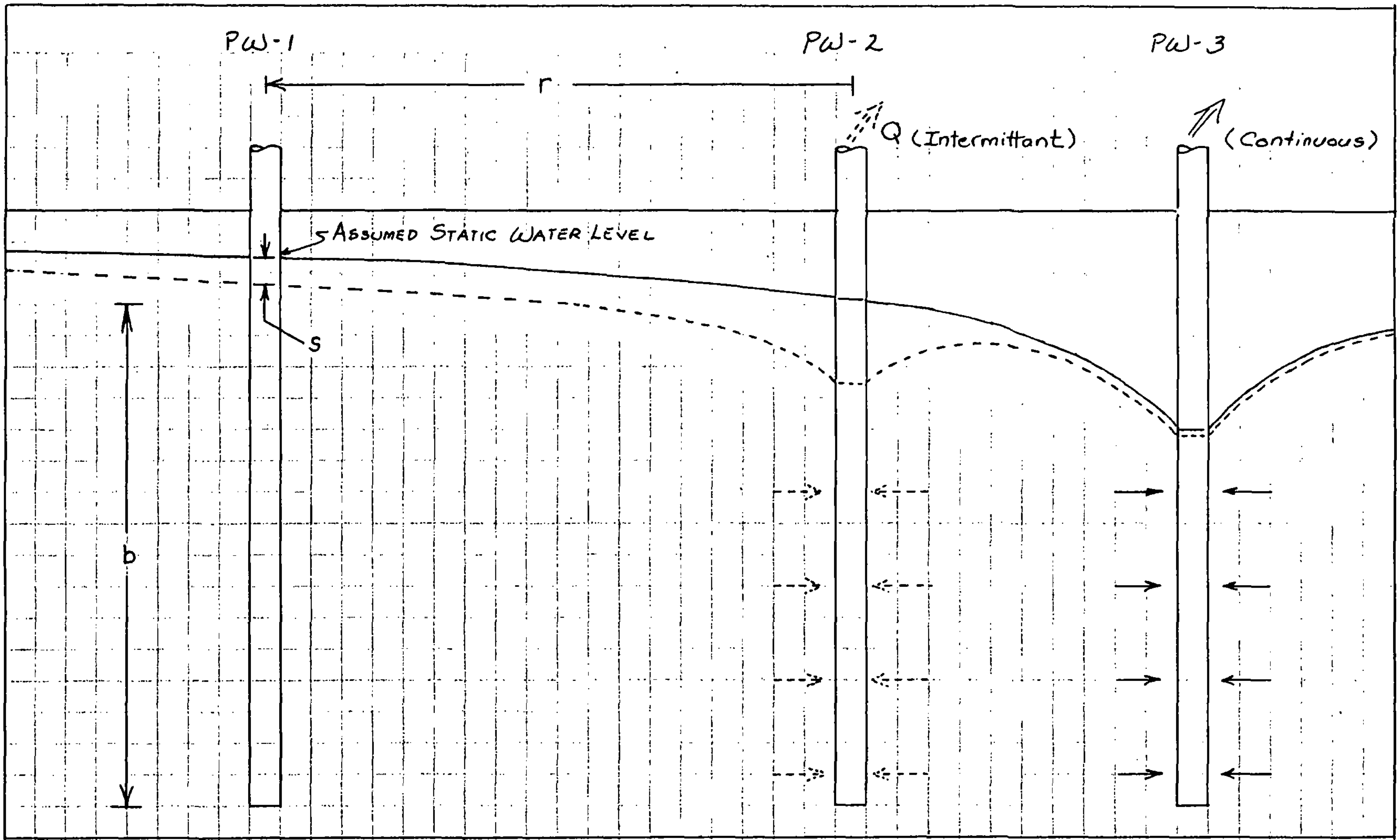
46 4970

K+E SEMI-LOGARITHMIC • 2 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.





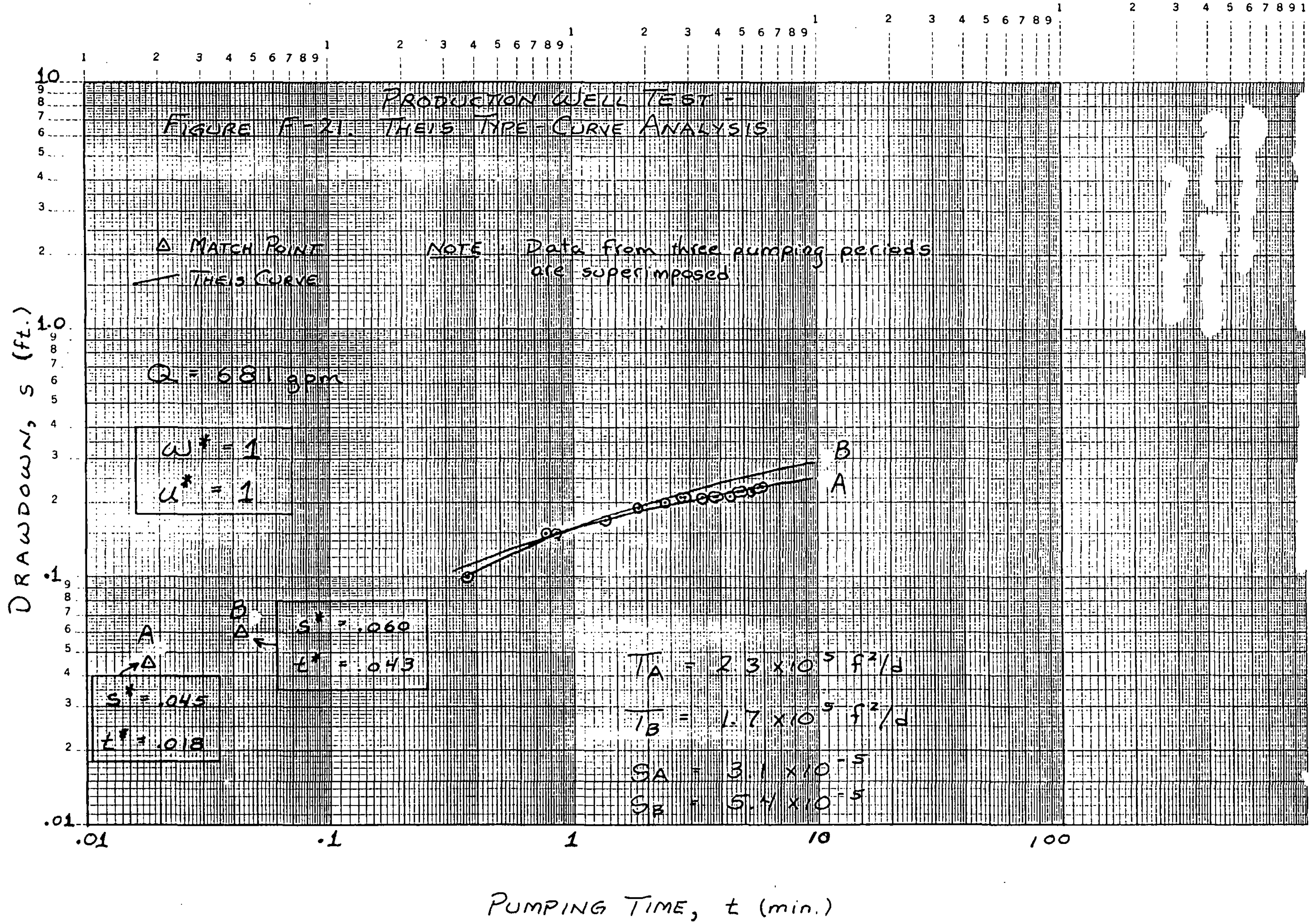
PRODUCTION WELL TEST -
FIGURE F-19. WATER-LEVEL HYDROGRAPH AT PW-1
DEPTH TO WATER (ft.)
100.10
100.20
100.30
100.40
1st PUMPING PERIOD
1st RECOVERY PERIOD
2nd PUMPING PERIOD
2nd RECOVERY PERIOD
3rd PUMPING PERIOD
PW-2 PUMPING SEQUENCE
2050
2055
2100
2105
2110
2115
2120
2125
2130
2135
CLOCK TIME

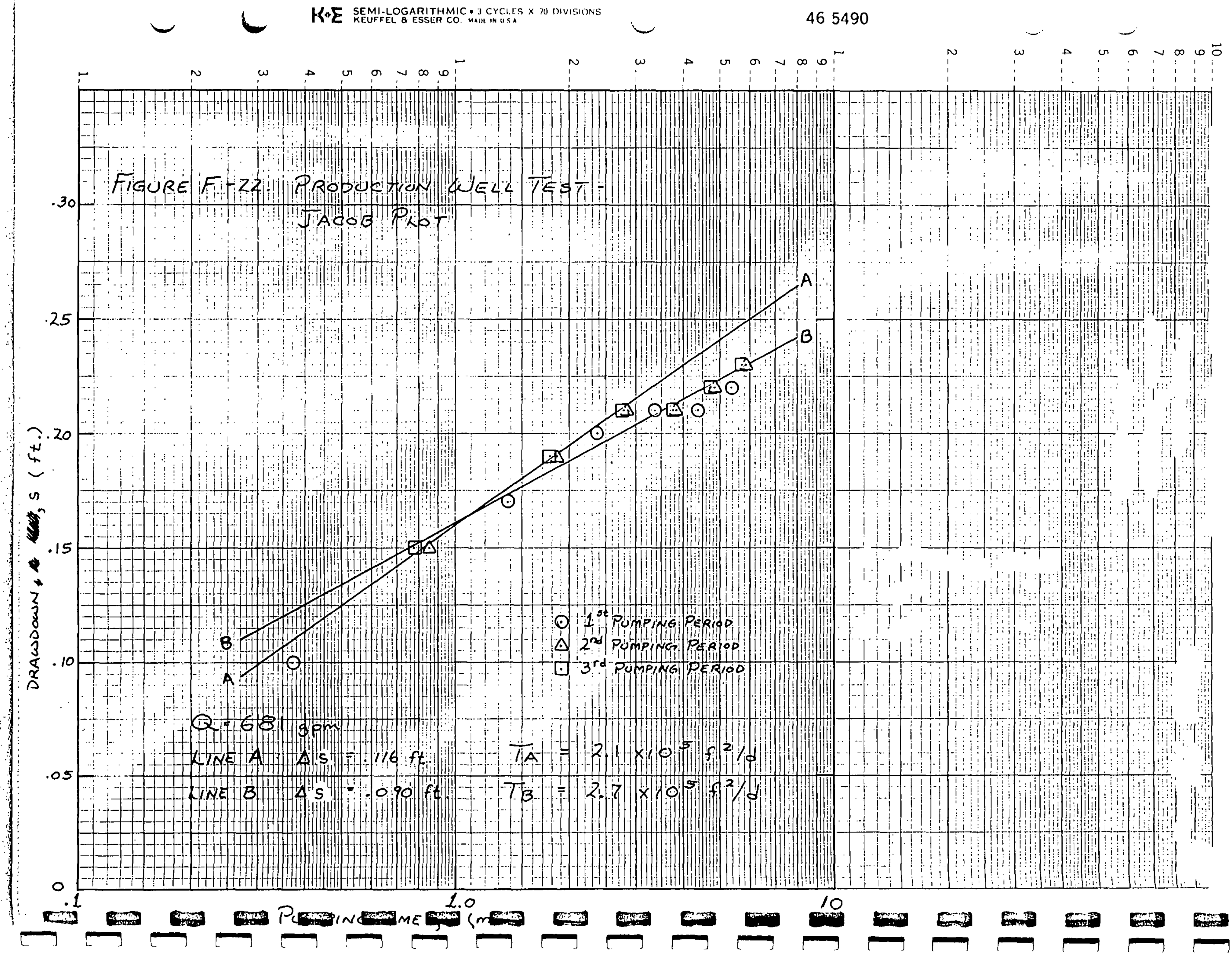


PW3 Steady-State Piezometric Surface (Cone of Depression)
Piezometric Surface After Superposition of PW-2 Hydraulic Response

Q = 681 gpm
r = 611 ft.
b = 150 ft.

FIGURE F-20. DIAGRAMATIC REPRESENTATION OF PRODUCTION WELL TEST CONDITIONS


PRODUCTION WELL TEST -
FIGURE F-21. THEIS TYPE-CURVE ANALYSIS
△ MATCH POINT
THEIS CURVE
NOTE Data from three pumping periods are superimposed
Q = 681 gpm
W* = 1
u* = 1
A
s* = .045
t* = .018
B
s* = .060
t* = .043
B
A
T_A = 2.3 x 10^5 f²/d
T_B = 1.7 x 10^5 f²/d
S_A = 3.1 x 10^-5
S_B = 5.4 x 10^-5
10
1.0
.1
.01
.01
.1
1
10
100
DRAWDOWN, s (ft.)
PUMPING TIME, t (min.)


K+E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 5490
FIGURE F-22 PRODUCTION WELL TEST -
JACOB PLOT
A
B
1st PUMPING PERIOD
2nd PUMPING PERIOD
3rd PUMPING PERIOD
Q = 681 gpm
LINE A Δs = .116 ft. TA = 2.1 x10^5 f^2/d
LINE B Δs = .090 ft. TB = 2.7 x10^5 f^2/d
DRAWDOWN, s (ft.)
.30
.25
.20
.15
.10
.05
0
.1
1.0
10

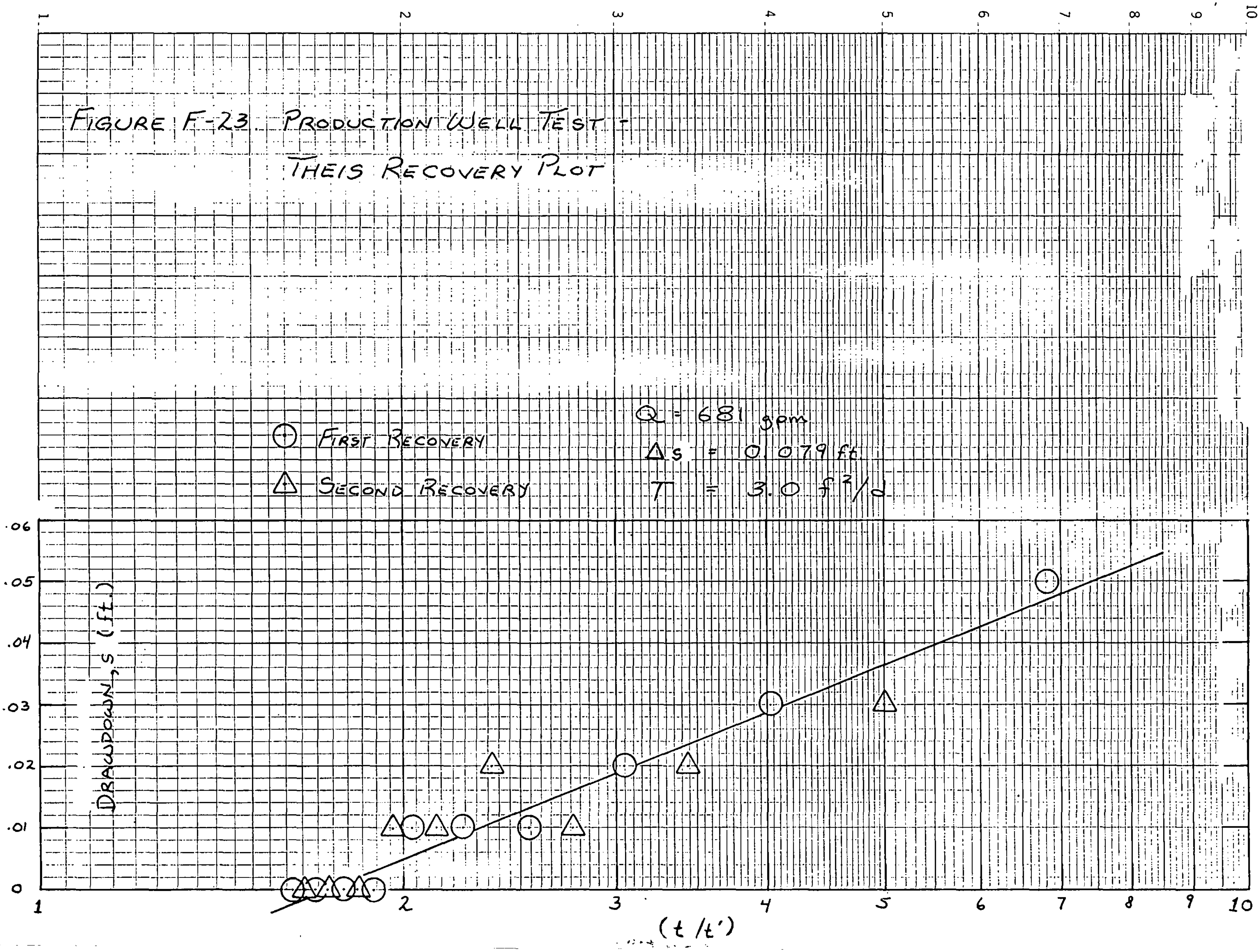


Figure F-23. Production Well Test - Theis Recovery Plot

FIGURE F-24. TW-20 PUMP TEST -
WATER LEVEL HYDROGRAPHS FOR TW-19 and TW-34

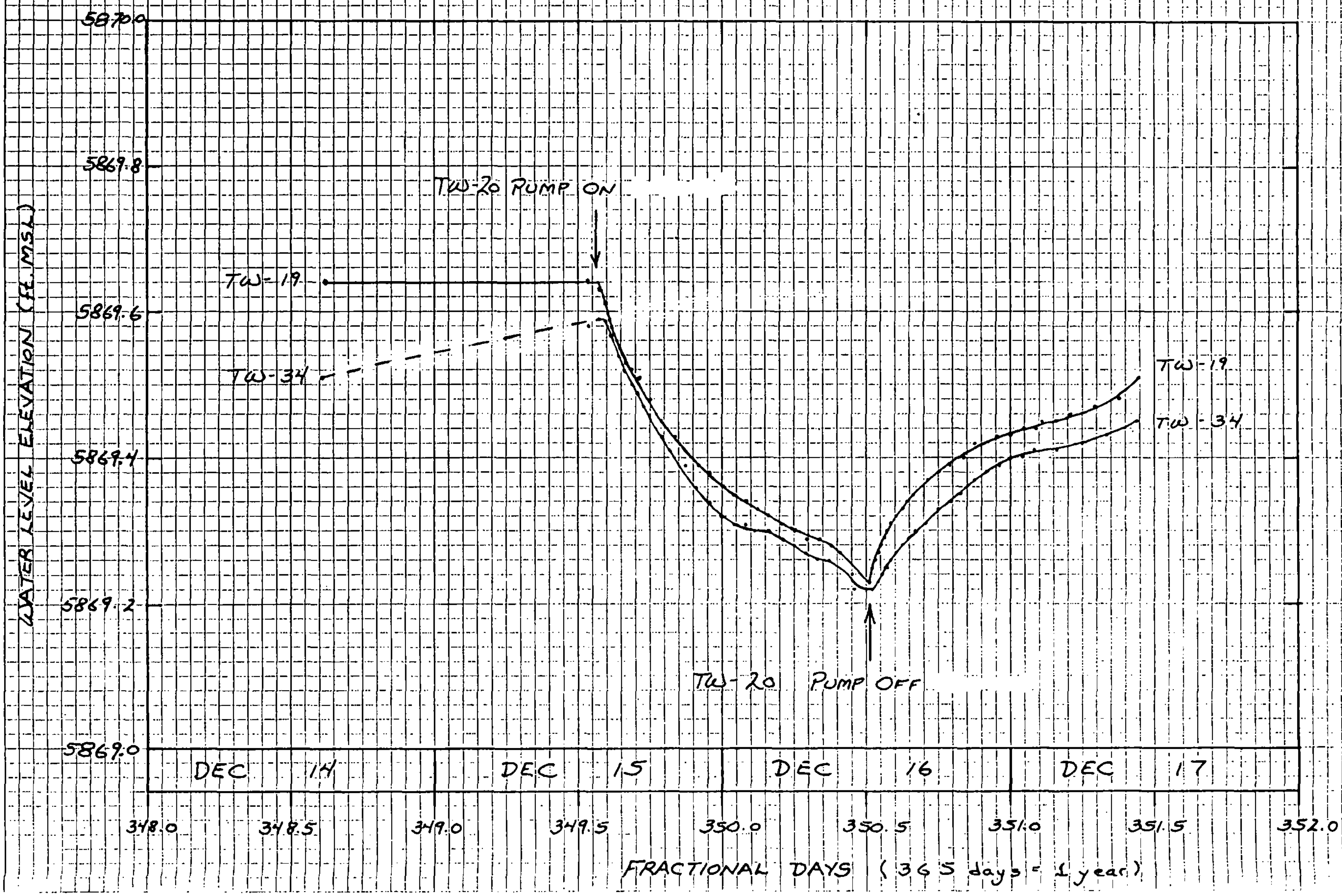
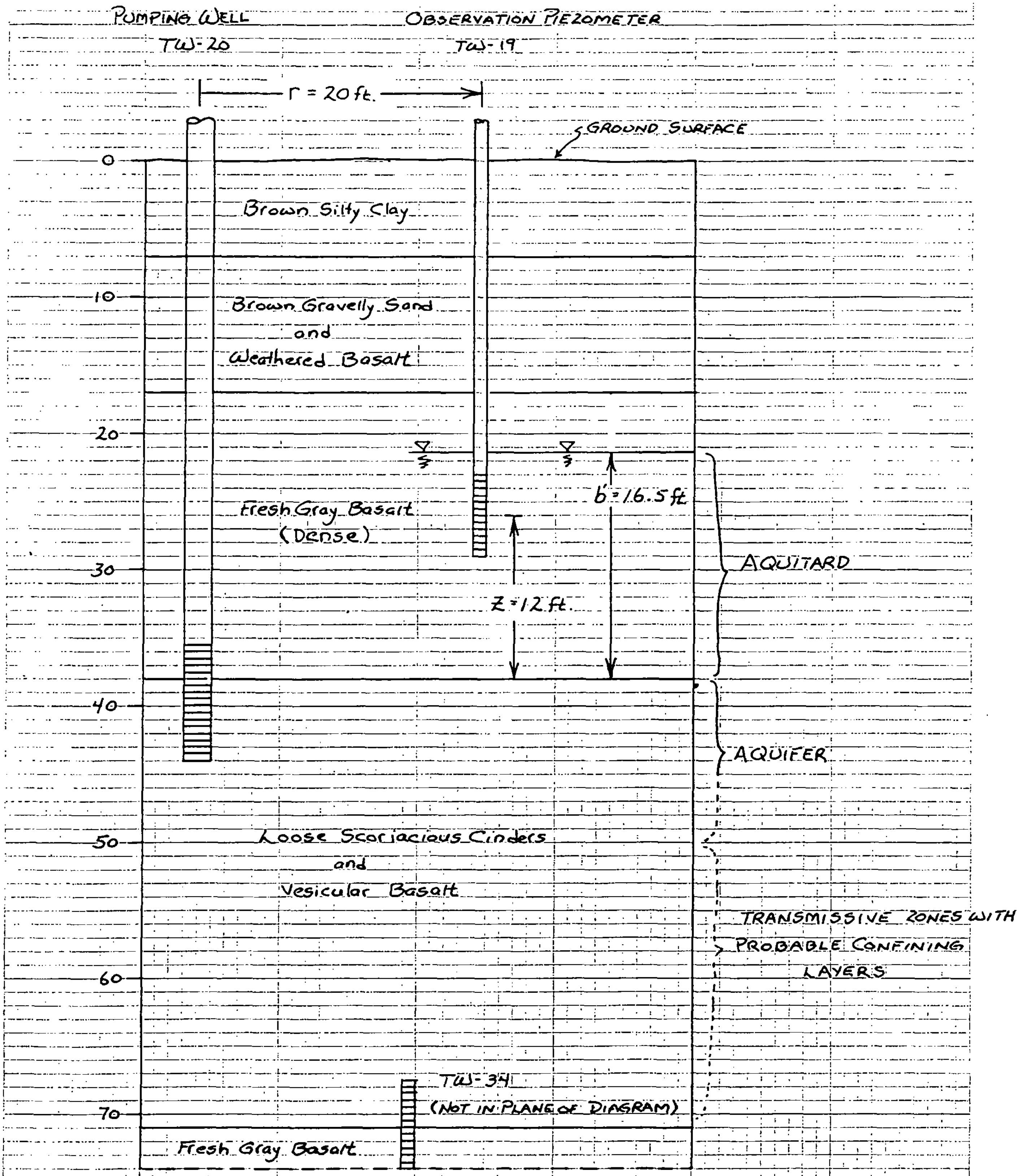
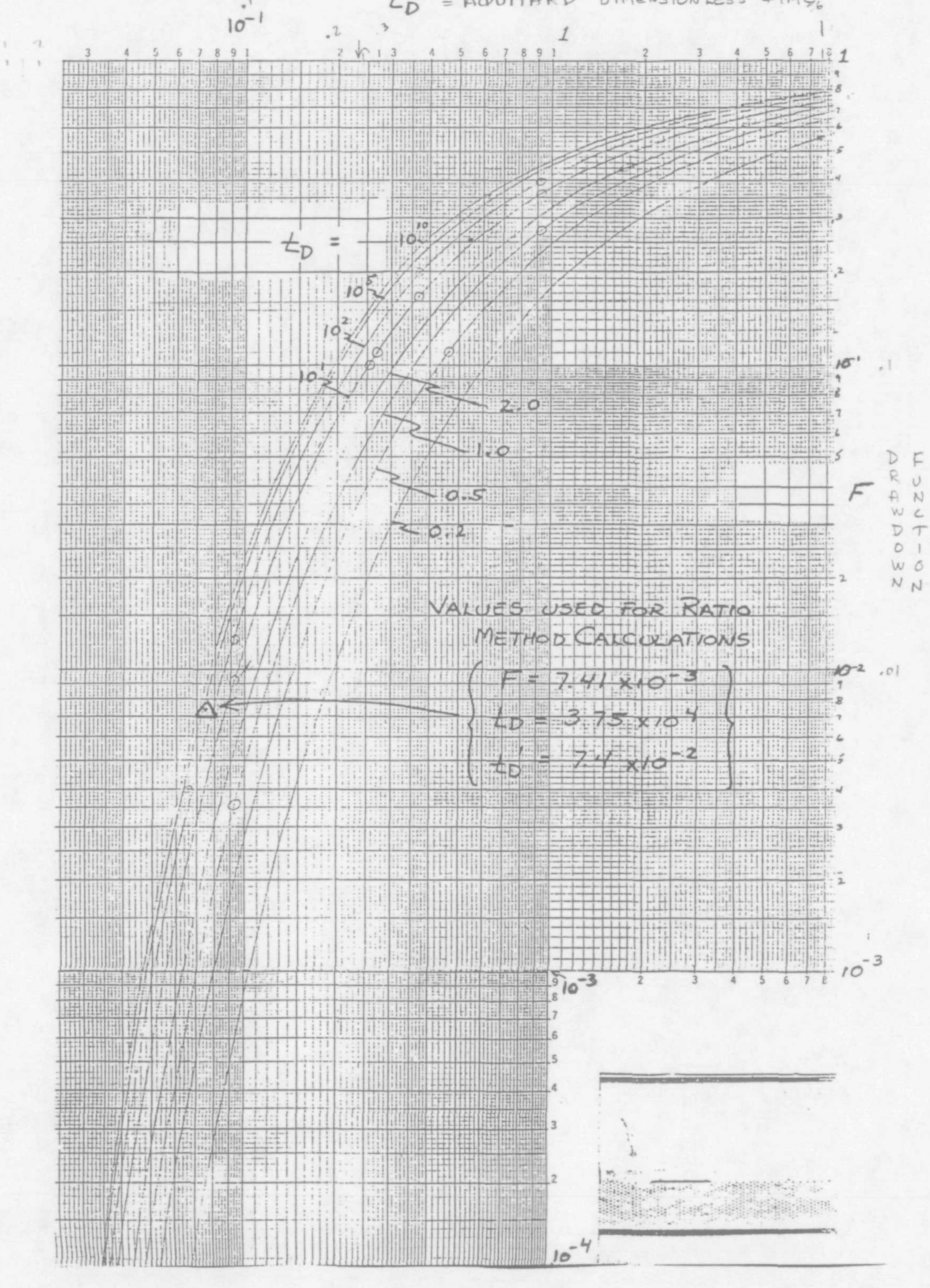


FIGURE F-25. TW-20 PUMP TEST - BOREHOLE LOCATIONS AND GENERALIZED STRATIGRAPHY



NOTE: Borehole diameters not to scale.

FIGURE F-26. TW-20 PUMP TEST -
RATIO METHOD CURVES



K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

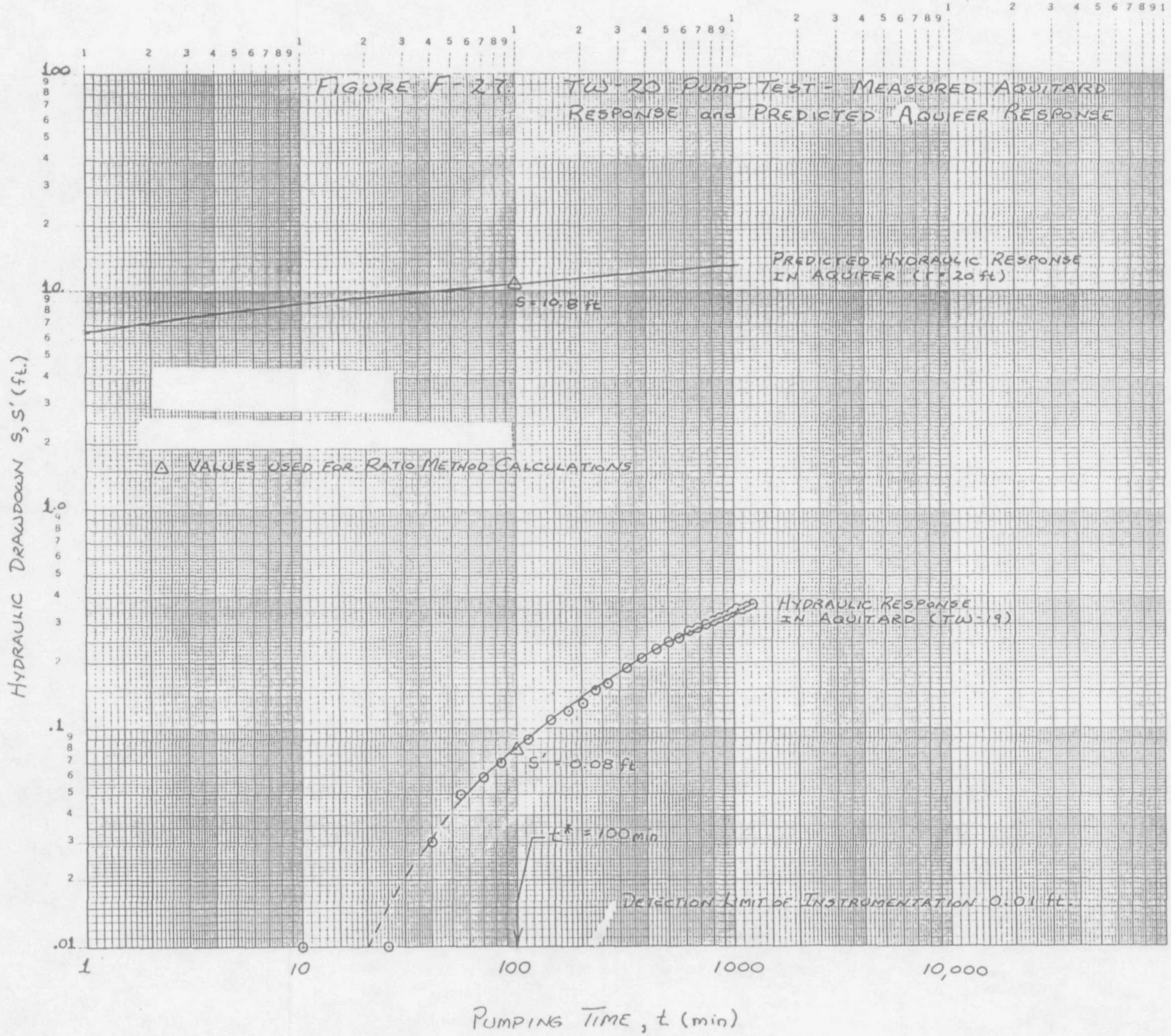


FIGURE F-27: TW-20 PUMP TEST - MEASURED AQUITARD RESPONSE and PREDICTED AQUIFER RESPONSE

pumped

Golder Associates	SUBJECT RISING HEAD TEST - TW25		
	Job No. 842-1543 Ref.	Made by DB Checked Reviewed	Date 23/5/85 Sheet 1 of

TW25

SWL = 28.25m $\qquad H_0 = 20.51m \qquad H =$ excess head at time (t)

Elapsed Time (mins)	DTW (m)	H/H_0
0	48.76 (160')	1.0
20	46.82	.905
180	37.83	.467

k = .038 f²/d/ft

T = .46 f²/d/ft.

"WEATHERED BASALT"

SWL = ~~28.25m~~ 6.955m

H_0 = 12.045m

TW34

Elapsed time (mins)	Depth to water (m)	H/H_0
0	19.0	1.0
13	16.805	.817
95	9.13	.180

k = .27 ft²/dy/ft

T = 1.76 ft³/d/ft

"CINDERS AND CLAY"

APPENDIX G

ANALYSIS OF WATER LEVEL OSCILLATIONS

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		Checked by	Date
		Approved by	Sheet No. 1

ANALYSIS OF WATER LEVEL OSCILLATIONS

Installation of Steven's recorders on selected test wells allowed for continuous water level monitoring, with an estimated resolution of better than 0.01 ft. Early in the field program, it was observed that water levels in some wells exhibited oscillations that were more or less sinsoidal in nature. To further investigate this phenomenon, Steven's recorders were temporarily installed on numerous test wells in order to determine the conditions under which oscillating water levels occurred.

Golder Associates	Subject	Made by	Job No.
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Test wells exhibiting water level oscillations are tabulated in Table G-1. Excluding measurements in TW-3, 4 and 5 (monitored with Johnson-Keck probe), the amplitude of water level oscillations ranged from 0.01 to 0.035 feet. The location of test wells exhibiting and not exhibiting oscillations is shown in Figure G-1. Test wells TW-25, 27, 29, 32 33, 34, 35, 37, 38, 39 and 40 had inconclusive or no Steven's recorder monitoring records; thus evaluation of oscillating water levels could not be made at these installations. Two important observations were noted after review of water level monitoring records:

1. Oscillations were observed in all piezometers deeper than 100 feet below the water table.
2. With the exception of two wells (TW-7, 26), oscillation were not observed in piezometers completed within 100 feet of the water table.

When background effects were filtered out, water level oscillations tended to be sinsoidal. As shown in Figure G-2, two characteristic responses were observed:

1. Semidiurnal (12 hour) oscillations (Figure G-2a)
2. Diurnal (24 hour) oscillations (Figure G-2b)

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In some wells, one type of response was observed to merge to the other type over a period of several days.

Possible explanations for the oscillating water levels are as follows:

- Hydraulic response to cyclic water well pumping on or off site
- Barometric effects
- Temperature effects (e.g., thermal expansion of wire cable to Steven's recorder float)
- Earth tides

Since the first three mechanisms would be expected to have only diurnal characteristics, they can not readily explain the existence of semidiurnal water level oscillations. Earth tides have both diurnal and semidiurnal components. Thus, it was felt that the effect of earth tides on observed water levels warranted further investigation.

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 4

<u>Interpretation of Water Level Oscillations as Earth Tides</u> Earth tides represent the superimposed effects of five principal constituents which account for 95 percent of the total tidal potential (Bredehoeft, 1967). Three of these components have semidiurnal periods ranging from twelve to thirteen hours, while two constituents have diurnal periods ranging from 24 to 26 hours. The magnitudes of diurnal components remain fairly constant through time, but semidiurnal constituents tend to decrease in magnitude during the first and last quarters of the moon. Earth tide induced water level oscillations result from tidal dilation of geologic materials and tends to be more pronounced in confined systems with low specific storage. If dilation is assumed to result from properties of the earth as a whole, ~~then~~ the magnitude of tidal dilation is directly related to tidal potential.

Figure G-3 compares the theoretical tidal potential with filtered water-level hydrographs of three wells (Rhoads and Robinson, 1979). Both theory and field observations indicate that semidiurnal oscillations are expected to occur during the new and full moon, while diurnal oscillations should occur during the first and last quarters of the moon. It is also observed in Figure G-3 that barometric pressure fluctuations do not readily correlate with phas[e] of the moon. In Figure G-4, the observed occurrence of semidiurnal and diurnal water level oscillations during the months of September and October are compared with phases of the moon. As theory would predict, semidiurnal oscillations occurred during the new and full moon and diurnal oscillations were observed during the first and third quarters. It is thus concluded that water level oscillations at the Soda Springs site are predominantly the result of earth tide effects.

Calculation of Specific Storage The amplitude of hydraulic buildup resulting from tidal dilation, is given by the following equation (after Bredehoeft, 1967; equation 25):

$$|S_{max}| = \frac{D}{S_s} \qquad (1)$$

where

S_{max} = amplitude of hydraulic buildup (i.e., change in hydraulic head)
D = amplitude of tidal dilation
S_s = specific storage

The amplitude of tidal dilation produced by a large semidiurnal wave is approximately 10^{-8} (Bredehoeft, 1967) and observed water level oscillations at the plant site have amplitudes on the order of 0.03 feet (Table G-1). Thus, substitution of

$$D = 10^{-8}$$

$$|S_{max}| = 0.03 \text{ ft}$$

into equation (1) and solving for S_s, gives the following approximate value for specific storage:

$$S_s \approx 3.3 \times 10^{-7} \text{ ft}^{-1} \; (1.1 \times 10^{-8} \text{ cm}^{-1})$$

The above specific storage ~~value~~ agrees closely with that determined from the production well pump test (Appendix F).

Calculation of Vertical Hydraulic Conductivity. In a perfectly confined system, water level oscillations resulting from earth tides will be roughly sinsoidal, with amplitudes that are directly proportional to the amplitude of tidal dilation. If the hydrologic system has significant vertical leakage, upward flow to the water table and subsequent depressurization at depth will result in attenuation of the water level oscillations. Thus, if vertical hydraulic diffusivity (K'/S_s) exceeds a critical value, the amplitude of the oscillations will be negligible, in which ~~...~~ case, vertical leakage would depressurize the system as rapidly as earth tide pressure changes are induced.

The following observations have been made regarding water level oscillations in test wells at the Soda Springs site:

- Oscillations are observed in all piezometers deeper than 100 feet below the water table
- Oscillations are generally not observed in piezometers completed within 100 feet of the water table.

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 7

The probable explanation for these observations is that vertical hydraulic conductivity decreases with depth. Presumably increased vertical leakage at shallow depths causes attenuation of the tidal response, while at greater depths, vertical leakage is insufficient to cause attenuation. Geologic studies at the site indicate a layered basalt sequence in which dense basalt is interlayered with vesicular basalt and cinder/rubble zones. Vertical leakage is controled primarily by the low permeability dense basalt units. Since flow in dense basalt is related to fracturing, the vertical hydraulic conductivity of this material would be expected to decrease with depth as fracture apertures become smaller due to increased overburden stress and possible mineral crystalization. ~~within the fractures~~.

With regard to vertical leakage, the physical ground water flow system is shown diagramatically in Figure G-5a. The system is assumed to be unconfined, but with decreasing vertical hydraulic conductivity with depth. In order to evaluate the system analytically, a two layer conceptual model is assumed, as shown in Figure G-5b. The boundary between the upper (high permeability) layer and the lower (less permeable) layer is assumed to be 100 feet below the water table. This is consistent with the observation that water level oscillations were generally not observed within 100 feet of the water table.

It is presumed here that vertical leakage in the upper layer is sufficient to effectively attenuate the earth tide hydraulic response. It is further assumed that vertical hydraulic conductivity in the lower layer is sufficiently small so that vertical leakage is negligible. This assumption seems reasonable considering the fact that piezometers more than 100 feet below the water table exhibit oscillations that do not appear to be attenuated. A consequence of this assumption is that negligible ground water flow would occur across the boundary between the two layers. Considering the scale of the problem (on the order of 100 feet), potential changes in position of the water table (resulting from tidal effects) can be neglected. Thus, the phreatic surface is assumed to represent an approximate constant head boundary.

The conceptual model is approximated analytically as the boundary value problem shown in Figure G-5c. The analytical model assumes one dimensional flow in an equivalent porous medium bounded above by a constant head boundary (phreatic surface) and below by a no flow boundary. Development and evaluation of an analytical solution to this boundary value problem is given in Attachments I and II. The analytical solution is modified from the analogous heat flow solution presented in Carslaw and Jaeger (1959; p131; equation 9). It is assumed in

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		Checked by	Date
		Approved by	Sheet No. 9

this solution that tidal dilatency can be described by a sine function of amplitude D,

$$A(t) = D \sin(\omega t) \qquad (2)$$

where

A = tidal dilatency

D = amplitude of tidal dilatency

ω = angular frequency

t = time

As derived in Attachment I, the final equation is

$$S_D = \sum_{n=0}^{\infty} \frac{2(-1)^n}{\left[\frac{(2n+1)\pi}{2}\right]} \cos\left[\frac{(2n+1)\pi z_D}{2}\right] \left\{ \frac{W_D}{\left[\frac{(2n+1)\pi}{2}\right]^4 t_D^2 + W_D^2} \right\} \cdot$$

$$\left\{ \left[\frac{(2n+1)\pi}{2}\right]^2 t_D \cos(W_D) + W_D \sin(W_D) - \left[\frac{(2n+1)\pi}{2}\right]^2 t_D \exp\left(-\left[\frac{(2n+1)\pi}{2}\right]^2 t_D\right) \right\}$$

which is expressed in terms of four dimensionless variables,

$S_D = \frac{s S_s}{D}$ (dimensionless hydraulic buildup)

$t_D = \frac{K t}{S_s \ell^2}$ (dimensionless time)

$\omega_D = \omega t$

$z_D = \frac{z}{\ell}$

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
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where

s = hydraulic buildup

K = vertical hydraulic conductivity

S_s = specific storage

ℓ = flow system thickness

z = vertical coordinate

The analytical solution was evaluated using a program written for an HP-41 hand-held calculator. A description of the algorithm is given is Attachment II. The following parameter values were assumed:

$\ell = 100$ ft

$S_s = 3.05 \times 10^{-7}$ ft^{-1} (10^{-8} cm^{-1})

$z = 0$ (base of upper layer)

$\omega = 2\pi$ day^{-1} (diurnal earth tide)

$K = 3.28 \times 10^{-10}$ to 3.28×10^{-5} ft/s
(10^{-8} to 10^{-3} cm/s)

A graph showing dimensionless buildup (s_D) vs. time (t) for various values of vertical hydraulic conductivity (K) is shown in Figure G-6. This represents the dimensionless hydraulic response occurring at the base of the upper layer due to earth tides. Figure G-6 leads to the following conclusions:

Golder Associates	Subject	Made by	Job No.
		Checked by	Date
		Approved by	Sheet No. 11

(1) For $K \leq 3.28 \times 10^{-9}$ ft/s (10^{-7} cm/s), the predicted response follows a sine curve. This indicates a conditions for which hydraulic buildup from earth tides is not attenuated by vertical leakage in the system

(2) For $K = 3.28 \times 10^{-7}$ ft/s (10^{-5} cm/s), the hydraulic response is significantly attenuated and for $K \geq 3.28 \times 10^{-6}$ ft/s (10^{-4} cm/s), the amplitude of the hydraulic response is negligible. In this case, vertical leakage would be sufficient to cause significant attenuation of the tidal response.

Since the purpose of this analysis is to simulate hydraulic response in a medium where oscillations were not observed, it is concluded that (2) is applicable to the shallow flow system at the Soda Springs site.

Based on the analysis performed herein, it is concluded that vertical hydraulic conductivity of the shallow flow system (within 100 feet of water table) is greater than 3×10^{-7} ft/s (10^{-5} cm/s). This represents a lower-bound value that is generally characteristic of the site as a whole. However, due to simplifying assumptions associated with the analytical solution, the above value should be considered, at best, an order of magnitude estimate.

Golder Associates	Subject	Made by	Job No.
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TABLE G-1. TEST WELLS EXHIBITING WATER-LEVEL OSCILLATIONS

BOREHOLE	PERIOD OF RECORD	AMPLITUDE (1) (ft.)	AVERAGE (2) DEPTH (ft. BGL)	DEPTH BELOW (3) WATER TABLE (ft.)
3	8/10 - 8/16	0.05 (4)	215	215
4	8/24 - 8/30	0.03 (4)	116	116
5	8/24 - 8/30	0.02 (4)	210	143
7	9/1 - 9/3	0.02	47	36
9	9/1 - 9/3 9/7 - 10/4	0.035	245	240
18	10/5 - 10/13	0.01	229	173
21	10/19 - 10/29	0.03	114	97
23	10/2 - 10/31	0.025	181	113
26	11/21 - 11/26 12/2 - 12/10	0.025	138	49

(1) Typical maximum amplitude of water-level oscillations excluding anomalously large values.

(2) Average depth of completed piezometer installation below ground level.

(3) Depth of piezometer below water table.

(4) TW-3, 4 and 5 monitored using Johnson-Keck geophysical probe. Measured amplitudes may not be accurate.

Note: Inconclusive or no monitoring records for TW-25, 27, 29, 32, 33, 34, 35, 37, 38, 39 and 40.

G-1

FIGURE . LOCATION OF TEST WELLS EXHIBITING AND NOT EXHIBITING WATER-LEVEL OSCILLATIONS

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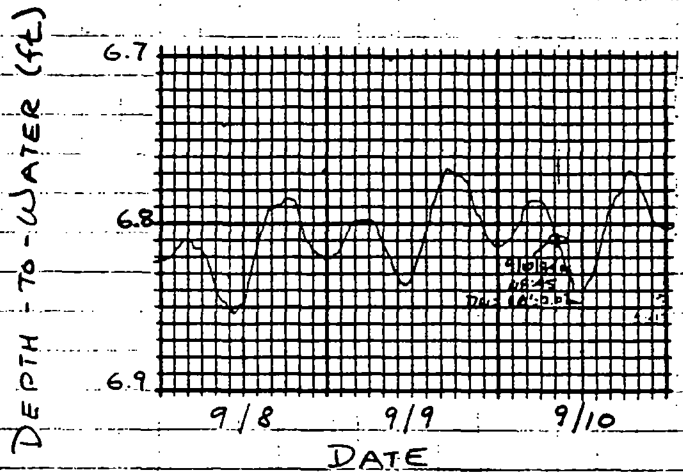
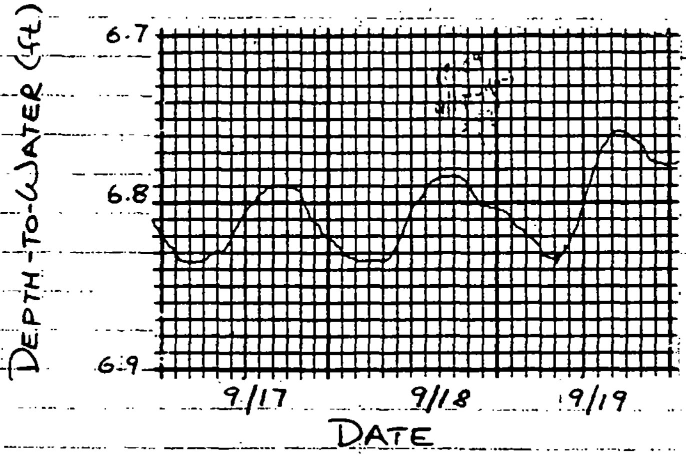
FIGURE 6-2. WATER-LEVEL OSCILLATIONS IN TW-9

a. Semidiurnal (12 hour) Oscillations



b. Diurnal (24 hour) Oscillations



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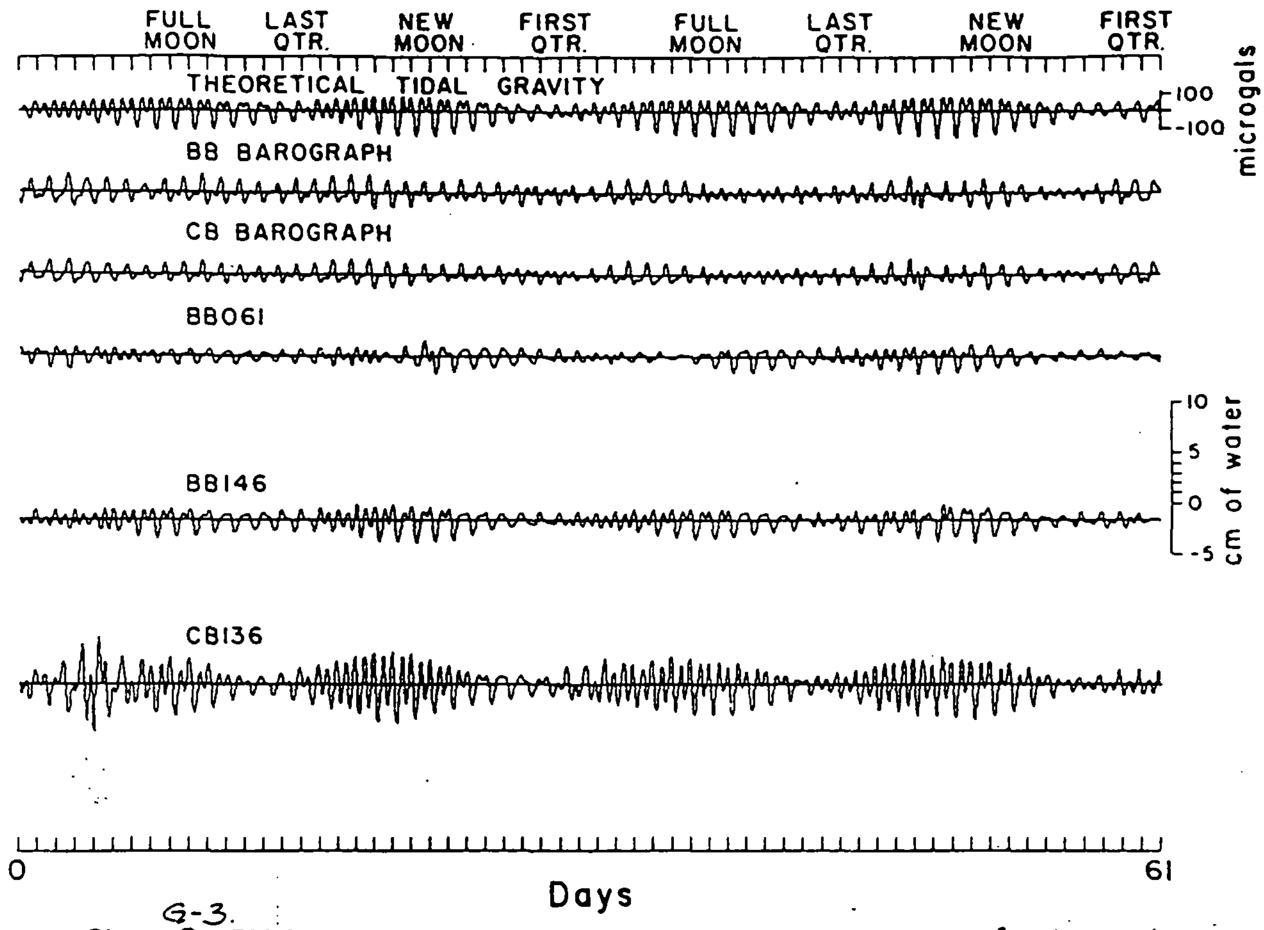

G-3.

Figure ●. Tidal water level and barometric pressure fluctuations at [redacted] observation wells obtained by harmonic filtering of observed hydrograph and barograph records.

(from Rhoads and Robinson, 1979)

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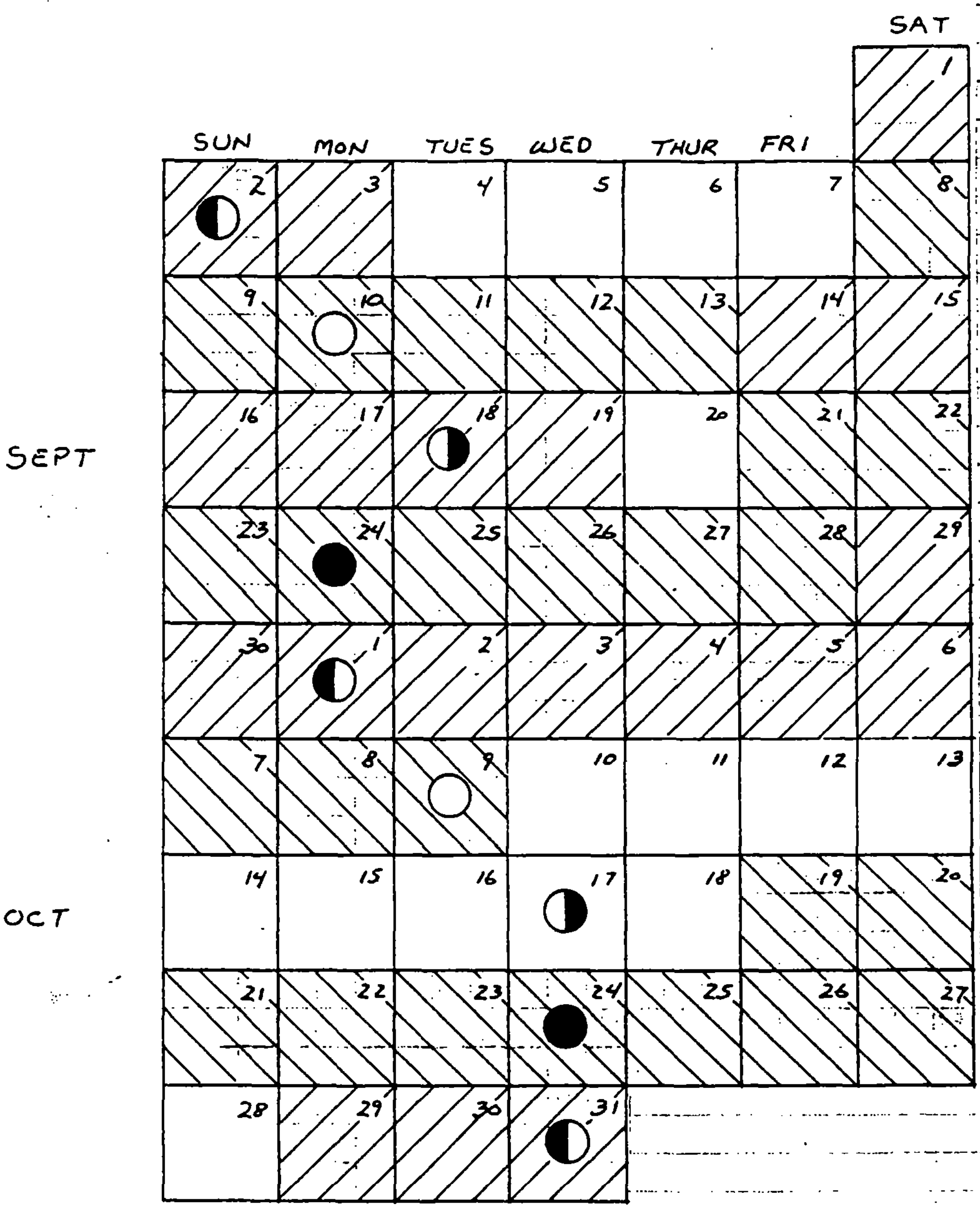
FIGURE G-4. OBSERVED WATER-LEVEL OSCILLATIONS AT SODA SPRINGS SITE



EXPLANATION

- ● NEW MOON
- ◐ FIRST QUARTER
- ○ FULL MOON
- ◑ LAST QUARTER

- OBSERVED DIURNAL OSCILLATIONS
- OBSERVED SEMIDIURNAL OSCILLATIONS
- OSCILLATIONS NOT DISCERNIBLE -OR- NO DATA AVAILABLE

Golder Associates	Subject	Made by	Job No.
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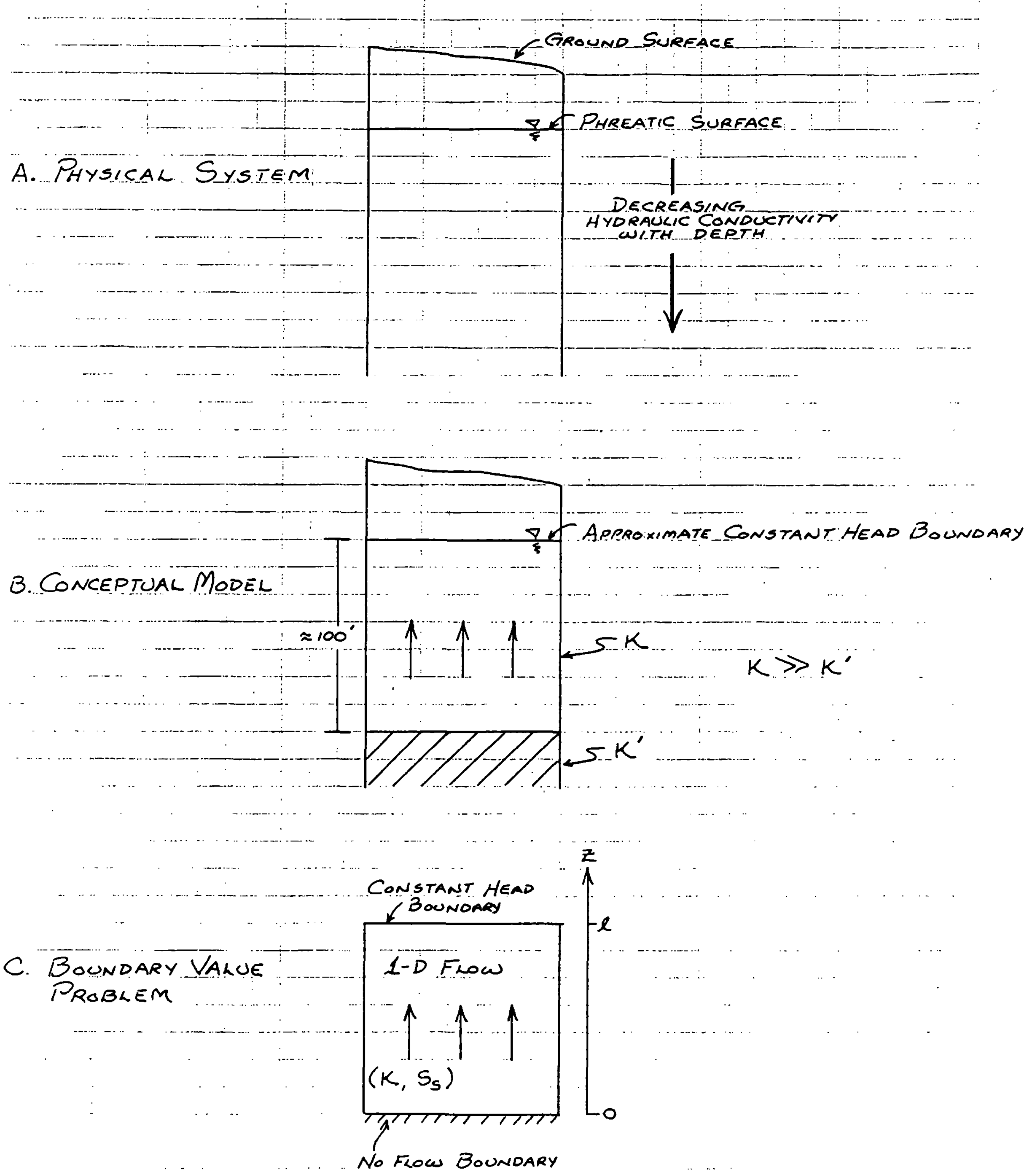
FIGURE G-5. DEVELOPMENT OF ANALYTICAL MODEL FOR EARTH TIDE HYDRAULIC RESPONSE



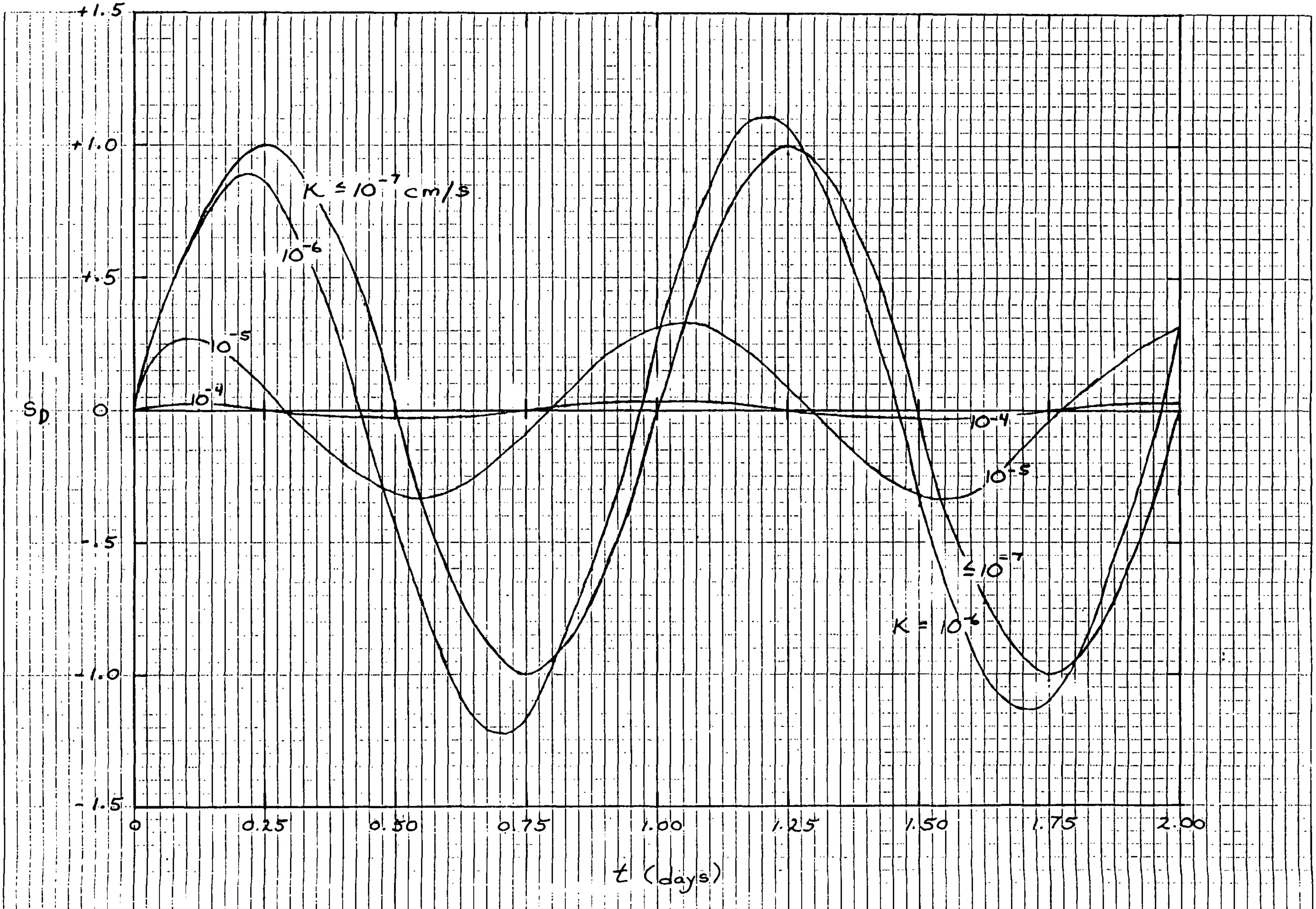


FIGURE 6-6. DIMENSIONLESS BUILDUP (S_D) vs. TIME (t) FOR VARIOUS VALUES OF VERTICAL HYDRAULIC CONDUCTIVITY K

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		Approved by	Sheet No. 1

ATTACHMENT I : DERIVATION OF ANALYTICAL SOLUTION

BOUNDARY VALUE PROBLEM

$$\frac{\partial^2 s}{\partial z^2} = \frac{S_s}{K}\frac{\partial s}{\partial t} - \frac{A(t)}{K} \quad \Big\} \text{ Governing Equation}$$

from Carslaw and Jaeger (1959; p 130; eq. 1) where A is a source of rate A per unit time per unit volume. Let:

$$A(t) = \frac{d}{dt}\left[D \sin(\omega t)\right] = D\,\omega \cos(\omega t)$$

$$s(z,0) = 0 \quad \Big\} \text{ Initial Condition}$$

$$\left.\begin{aligned} s(\ell, t) &= 0 \\ \left.\frac{\partial s}{\partial z}\right|_{z=0} &= 0 \end{aligned}\right\} \text{ Boundary Conditions}$$

SOLUTION (Carslaw and Jaeger, 1959; p 131; eq. 9)

$$s = \frac{4}{\pi S_s}\sum_{n=0}^{\infty}\frac{(-1)^n}{(2n+1)}\cos\left[\frac{(2n+1)\pi z}{2\ell}\right]\int_0^t A(\tau)\exp\left[\frac{-K}{S_s}\frac{(2n+1)^2\pi^2(t-\tau)}{4\ell^2}\right]d\tau$$

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Substituting $A(\tau) = D\,\omega \cos(\omega\tau)$, carrying out the integration, and simplifying, results in the following equation :

$$s = \frac{4D}{\pi S_s} \sum_{n=0}^{\infty} \frac{(-1)^n}{(2n+1)} \cos\left[\frac{(2n+1)\pi z}{2\ell}\right] \cdot$$

$$\left[\frac{\omega t}{(Mt)^2 + (\omega t)^2}\right]\left[Mt\cos(\omega t) + \omega t \sin(\omega t) - Mt\, e^{-Mt}\right]$$

where : $M = \frac{K}{S_s}\left[\frac{(2n+1)\pi}{2\ell}\right]^2$

The above equation can be expressed in terms of four dimensionless variables,

$S_D = \frac{s\,S_s}{D}$ (dimensionless hydraulic buildup)

$t_D = \frac{Kt}{S_s \ell^2}$ (dimensionless time)

$W_D = \omega t$

$Z_D = \frac{z}{\ell}$

resulting in the final dimensionless equation,

$$s_D = \sum_{n=0}^{\infty} \frac{2(-1)^n}{\left[\frac{(2n+1)\pi}{2}\right]} \cos\left[\frac{(2n+1)\pi Z_D}{2}\right] \left\{\frac{W_D}{\left[\frac{(2n+1)\pi}{2}\right]^4 t_D^2 + W_D^2}\right\} \cdot$$

$$\left\{\left[\frac{(2n+1)\pi}{2}\right]^2 t_D \cos(W_D) + W_D \sin(W_D) - \left[\frac{(2n+1)\pi}{2}\right]^2 t_D \exp\left(-\left[\frac{(2n+1)\pi}{2}\right]^2 t_D\right)\right\}$$

ATTACHMENT II : HP-41 PROGRAM "OWL"

S_1 : $t_D = \dfrac{Kt}{S_s \ell^2}$

S_2 : $W_D = \omega t$ — INPUT MEMORY

S_3 : $Z_D = \dfrac{x}{\ell}$

S_{11} : $\dfrac{(2N+1)\pi}{2}$

S_{12} : $\left[\dfrac{(2N+1)\pi}{2}\right]^2 t_D$ — INTERNAL MEMORY

S_{10} : N

S_{13} : $\sum_{n=0}^{N} (\ldots\ldots) = \sum_{n=0}^{N} s_{DR}$

NOTE: S_j indicates memory in storage register j

$$s_{DN} = \sum_{n=0}^{N} \frac{2(-1)^n}{S_{11}} \cos\left[S_{11}\cdot S_3\right] \left\{ \frac{S_2}{S_{12}^2 + S_2^2} \right\} \cdot \left\{ S_{12}\cos(S_2) + S_2 \sin(S_2) - S_{12}\exp(-S_{12}) \right\}$$

PROCEDURE

1. Input t_D, W_D, Z_D into storage registers 1, 2, 3, respectively
2. EXQ "OWL"
3. Press STOP when s_{DN} has converged to a solution

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	Checked by	Date
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PROGRAM LISTING

01	LBL^T OWL
02	Ø
03	STO 1Ø
04	STO 13
05	LBL Ø1
06	RCL 1Ø
07	2
08	*
09	1
10	+
11	PI
12	*
13	2
14	/
15	STO 11
16	X↑2
17	RCL Ø1
18	*
19	STO 12
20	-1
21	ENTER↑
22	RCL 1Ø
23	Y↑X
24	2
25	*
26	RCL 11
27	/
28	RCL 11
29	RCL Ø3
30	*
31	COS
32	*
33	RCL 12
34	X↑2
35	RCL Ø2
36	X↑2
37	+
38	1/X
39	RCL Ø2
40	*
41	*
42	RCL 12
43	CHS
44	E↑X
45	RCL 12
46	*
47	CHS
48	RCL Ø2
49	SIN
50	RCL Ø2
51	*
52	+
53	RCL Ø2
54	COS
55	RCL 12
56	*
57	+
58	*
59	RCL 13
60	+
61	STO 13
62	PSE
63	RCL 1Ø
64	1
65	+
66	STO 1Ø
67	GTO Ø1
68	END